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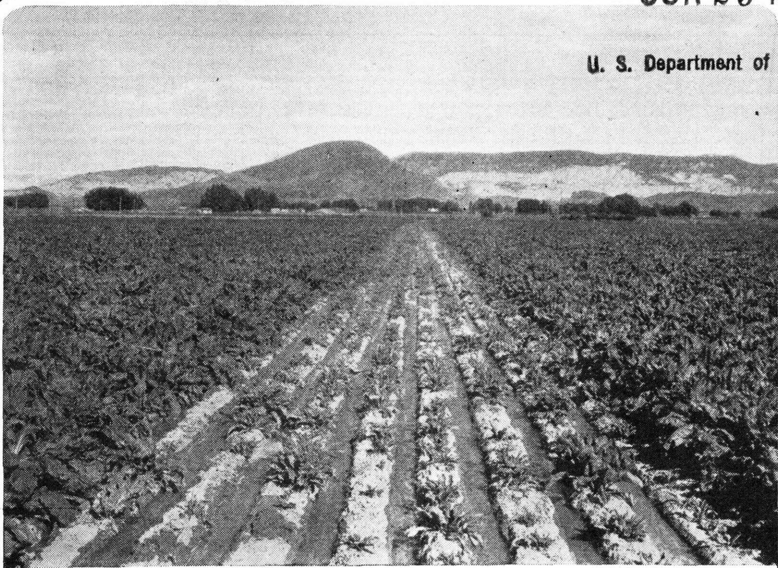

# SUGAR-BEET CULTURE

IN THE INTERMOUNTAIN AREA WITH CURLY TOP RESISTANT VARIETIES

FARMERS' BULLETIN No. 1903
U. S. DEPARTMENT OF AGRICULTURE

SUGAR-BEET PRODUCTION, important in peacetime agriculture, becomes in wartime a vital part of the national effort. As a basic foodstuff, sugar provides about 13 percent of all the energy we get from foods. Our national requirement of sugar, always large, becomes in wartime very great, because sugar is used not only for our fighting forces and those of our allies, but also as a source of industrial alcohol essential for munition manufacture. Rationing for civilian uses represents one method of obtaining these necessary supplies; on the other hand, much can be done to increase supplies by strongly stepping up production. Every additional acre planted to sugar beets and every extra ton of sugar on the increased acreage resulting from better farming contributes to the country's effort. Now is the time to apply all the knowledge gained by research in recent years.

This bulletin outlines for the Intermountain States improved practices established by agricultural research and practical farming operations. Such practices begin with the choice of adapted fields and a careful seeding of the fields with the right variety. They include the care and protection of the growing crop and its harvest at proper season. These essentials of good husbandry must be exercised in the face of labor and machinery shortages, because, in this emergency period, no backward steps should be taken. This bulletin on improved practices in sugar-beet culture should assist farmers in their steady advances in better crop production.

Resistant varieties, developed by the United States Department of Agriculture, have removed much of the threat of curly top epidemics, and, in contrast to World War I conditions, adequate supplies of seed of these improved American varieties are available.

Sugar-beet byproducts are discussed and directions given for efficient utilization. The sugar beet has always been recognized as having a close alliance with livestock industries—dairying and animal feeding. The valuable byproducts from the sugar beet (tops, pulp, and sugar-beet molasses) have a recognized and significant value as feeds for farm animals. The wartime requirements for more milk and other dairy products and for more meat make imperative effective utilization of these valuable feeds.

This bulletin supersedes Farmers' Bulletins 1645, Sugar-Beet Growing Under Irrigation in the Utah-Idaho Area, and 567, Sugar-Beet Growing Under Irrigation.

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# SUGAR-BEET CULTURE IN THE INTERMOUNTAIN AREA WITH CURLY TOP RESISTANT VARIETIES

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## Contents



## FOREWORD

THE EVENTS that have followed in rapid succession since Pearl Harbor have pushed sugar into the foreground of the agricultural picture. In wartime, the calls for this essential foodstuff greatly increase. Our fighting forces and those of our allies must be supplied. Sugar is needed for the increased production of industrial alcohol for use in the manufacture of munitions and other war materials. The problem of adequate food supply for civilian populations does not lessen. For such uses as the preserving and canning of perishable foodstuffs, sugar is almost irreplaceable. As these demands have increased, the islands of the Pacific, which in normal times supply a considerable portion of our sugar requirements, have either been cut off or face difficulties in shipping.

Rationing of sugar for civilian uses represents the immediate, necessary step to insure that military requirements are met. Coupled with this program there is needed the expansion of domestic production in order that our farm lands may contribute to the fullest extent in the emergency. In peacetime, domestic production of sugar from sugar beets and sugarcane has provided about 30 percent of the national requirement, the sugar beet furnishing about 23 percent. Acreage restrictions on sugar crops are now removed, and benefit payments to farmers growing these crops have been increased.

Everything points to a greatly increased sugar-beet acreage in the United States, which will utilize suitable land and factory capacity

to the limit. The sugar-beet districts in the intermountain area have normally produced about 20 percent of the total beet sugar manufactured in the United States. In general, farmers in this area have produced high tonnages of sugar beets of very high quality. The possibilities for the sugar-beet districts very strongly increasing their total production of sugar are good. Such increase can come if the acreage of beets grown is increased as a response to the Nation's call, and if, on this increased acreage, still higher levels of productivity are reached because farmers make use of the best practices in growing the crop. The purpose of this bulletin is to emphasize these practices in order that the crop may be the best attainable.

## THE PLACE OF SUGAR BEETS IN A PERMANENT SYSTEM OF AGRICULTURE FOR THE INTERMOUNTAIN AREA

THE SUGAR-BEET INDUSTRY has played a significant part in the development of a permanent system of agriculture in the irrigated districts of western Colorado, Utah, Idaho, eastern Oregon, and eastern Washington, all within the intermountain area. As these States are distant from markets, cash crops that are convertible at home into a condensed form for marketing are essential elements in the farming program. In this semiarid country irrigation is the lifeblood of the land. Therefore, the sugar-beet crop, which grows well under irrigation and whose product, sugar, is marketed in refined form, is admirably suited to the requirements of intensive irrigation agriculture in this area.

The widespread influence of sugar beets on the agriculture of the Intermountain States can be visualized somewhat when one considers the fact that in Utah an average of nearly 8,000 farmers annually grow sugar beets and that an average of 54,000 acres is devoted to sugar-beet production. About 12 to 15 percent of Utah's total crop value comes from sugar beets, which occupy only 5 percent of the arable or cultivated land. In comparison, alfalfa produces about 32 percent of the crop income and occupies about 45 percent of the total crop area, whereas small grains produce about 22 percent of the total farm income and occupy about 31 percent of the area. Acre for acre, the income from sugar-beet land in the intermountain area is more than three times as great as from alfalfa or grain. Sugar beets fit well into a system where livestock, alfalfa, grain, and cultivated crops are combined to establish a permanent and profitable agriculture.

Wide fluctuations in production, which occurred in Utah and Idaho between 1920 and 1930, were caused largely by severe outbreaks of curly top. During the years curly top caused most damage, acre yields were reduced to as little as 7 tons in Utah and 6 tons in Idaho. In the State of Washington, factories in the Yakima Valley were abandoned because of the ravages of curly top. In 1934, drought and curly top greatly reduced the sugar-beet crop in Utah, the average acre yield being only 7.8 tons.

The first successful beet-sugar factory in Utah was established in 1891. In Idaho the first factory was built in 1903 at Idaho Falls and is still operating. Following these pioneering ventures, the acreage devoted to the culture of sugar beets in the Intermountain States has increased, and many factories have been built (fig. 1). Under stimulus of World War I conditions, sugar-beet acreage increased in

Utah and Idaho until a peak was reached in 1920, when in the former State 113,000 acres were harvested, producing 1,261,000 tons of sugar beets, and in the latter 405,000 tons of sugar beets were grown on 45,000 acres. In the decade 1921–30, production of sugar beets in Idaho varied from a low in 1926 of 108,000 tons, produced on 18,000 acres harvested, to a high of 492,000 tons, produced on 48,000 acres in 1929. In Utah, acreage dropped more or less gradually from over 100,000 acres to about 45,000.

In the decade 1931–40, the average acreage in Idaho was about 56,500 acres, ranging from a low of 33,000 in 1931 to acreages of over 70,000 in 1933, 1938, 1939, and 1940. For the decade 1931–40, the 10-year average of sugar-beet acreage in Utah was 48,700 acres, with an average production of 609,000 tons.

Beginning with the 1935 crop year, extensive plantings were made with seed of curly top resistant varieties, which had been developed by the Division of Sugar Plant Investigations of the United States Department of Agriculture in cooperation with the beet-sugar companies of the curly top area. Since that time, acre yields have not fallen below an average of 10.5 tons in Utah and 11.02 in Idaho. Use of curly top resistant varieties has not only stabilized but has, in some sections, revived the industry. This is concretely shown by the rebuilding of a beet-sugar factory in the Yakima Valley of Washington in 1937 on the site of a factory abandoned in 1924 because of curly top, and by the reentrance of the sugar beet into districts previously made too hazardous because of this disease. In the Yakima Valley, since 1938, there has been an average of 14,000 acres of sugar beets harvested with an average yield of approximately 16 tons per acre. Western Idaho and eastern Oregon irrigated districts have been recognized as areas in which curly top is likely to cause very severe injury to the crop. The new factory built in 1938 at Nyssa, Oreg., to serve these districts has had, on an average, about 17,000 acres planted to sugar beets with an average yield in excess of 15 tons per acre. Similarly, areas in Utah where curly top previously made sugar beets unprofitable have started again into sugar-beet production.

In Idaho, Washington, and Oregon there has been a gradual increase in acreage, and this would have continued in normal times if the domestic market had been such as to lend encouragement to the industry. Under the stress of war demands for more production of sugar, the increase in acreage undoubtedly will be greatly accelerated. In Utah, increase in acreage will take place but probably will not reach the expansion that took place in World War I. In both Utah and Idaho, aside from competing crops and other factors that will influence expansion of acreage, the problems involved in sugar-beet nematode control are important. Many fields otherwise suitable are infested with nematodes. Sugar-beet cropping cannot be repeated in such fields, and a rotation of 4 to 5 years is necessary before the field can advantageously be used for sugar beets. Discriminating selection of fields for sugar beets is necessary in order that the urge for greater acreage shall not in fact result in wasted effort because of heavy losses from nematode injury.

The improved situation of the sugar-beet industry in the intermountain area has come about from a number of factors among which the use of curly top resistant varieties has been significant. Use of the resistant types has been accompanied by more careful

farm planning and the adoption of rotation systems that help bring nematode infestations under control and help maintain a higher level of soil fertility.

The importance of sensible soil treatment and a proper farming program has been shown during years when curly top and other unfavorable factors have reduced average yields to 6 and 7 tons per acre. Even in these poor years, some farmers obtained yields of from 15 to 18 tons per acre. The same relationship is evident in good years when average acre yields range from 12.5 to 14.0 tons per acre; many farmers, by following good farming practices, obtain yields of 25 to 28 tons. Practices established by agricultural research and practical farming operations will enable the farmer to make sugar beets a more profitable crop and a more permanent part of his agriculture.

## FACTORS IN PRODUCTION

The major factors in sugar-beet production in Utah, Idaho, Oregon, and Washington are: (1) Use of curly top resistant varieties; (2) cultural practices; (3) seed sources; (4) climate; (5) soil requirements; and (6) irrigation supply.

### CURLY TOP RESISTANT VARIETIES

Curly top is a virus disease of sugar beets and other plants transmitted by the beet leafhopper. Description of the disease and discussion of its relationship to the insect vector are given on page 42.

Curly top control by the use of resistant varieties began with the release of the variety U. S. 1. This variety was sometimes damaged by drastic curly top exposure, because many of the individual plants were only moderately resistant. However, the variety averaged high enough in resistance so that a great advance was made with it toward satisfactory curly top control. U. S. 1 was shortly superseded by the varieties U. S. 33 and U. S. 34. U. S. 12 replaced U. S. 34 in 1938, and the variety A–600, developed by the Amalgamated Sugar Co., was also planted extensively for a few years. More recently U. S. 22, a higher yielding variety with a higher degree of curly top resistance, was released. Sufficient seed of U. S. 22 has been grown so that it will be widely used in the intermountain curly top area in 1942 and 1943.

Under severe curly top exposure, U. S. 22 has shown marked superiority to U. S. 33. In 1940, tests at Buhl, Idaho, U. S. 22 yielded 27.1 tons per acre in an April 10 planting, as compared with 19.3 tons for U. S. 33. The curly top exposure was such that the nonresistant European variety, R. & G. Old Type, was reduced in yield to 5.2 tons per acre. On the same field, in a planting made especially late (June 6) to make curly top exposure extreme, Old Type was a complete failure; U. S. 33 yielded 4 tons per acre; and U. S. 22 yielded 9.5 tons per acre. U. S. 33 is a better sugar type, however, and is a fine variety for many areas where curly top is not too severe. The cover illustration shows a field of the curly top resistant U. S. 33 variety, and a few rows of a nonresistant European variety planted as a center strip.

Under severe curly top exposure, accompanied by unfavorable growing conditions, such as the varieties are purposely subjected to in experimental fields, the development of curly top symptoms has made

obvious the variable nature of plants within a variety. This variability has also been observed in farmers' fields wherever the curly top exposure has been sufficiently severe. As curly top resistance has been gradually improved, much of this variability has been eliminated, but even the highly resistant variety U. S. 22 is affected by curly top to some extent.

## CULTURAL PRACTICES AND CURLY TOP RESISTANCE

Environmental conditions have much to do with the performance of curly top resistant sugar-beet varieties. The resistance of varieties increases rapidly with size and age of the plants, and curly top does not do serious damage during cool weather.

Because of the relationship of temperature and plant size to varietal resistance, the matter of getting the crop off to an early start is the most important point in avoiding injury from curly top. This involves timely seedbed preparation, early planting, ample fertility, and early irrigation. Obviously, all of these factors have a direct influence on the size plants will have attained by the time beet leafhoppers migrate into the fields. Plant size and early irrigation also have a direct influence upon soil temperatures. Shaded soil and soil made cool by irrigation offer a favorable environment for growth of the beet and an unfavorable environment for the increase of leafhopper populations.

Since the introduction of curly top resistant varieties of sugar beet, the majority of crop failures associated with curly top damage have been due to late planting, poor soil fertility, or failure to provide early irrigation. In many cases, more than one of these factors have been responsible. Farmers in the areas where curly top has been most severe, who appreciate fully the importance of the above factors and follow cultural practices that enable the sugar-beet plant to take full advantage of its inherited resistance, frequently produce in excess of 20 tons of beets per acre, even in years of serious curly top exposure.

## SEED OF IMPROVED SUGAR-BEET VARIETIES

Commercial seed for grower use of the curly top resistant varieties resulting from breeding work of the United States Department of Agriculture is produced from lots designated as stock seed. Stock seed is produced from elite seed, which, in turn, comes directly from breeders' strains obtained in the curly top resistance breeding research of the United States Department of Agriculture. Special attention has been given to provide adequate and choice supplies of elite and stock seed. Elite seed is held in fireproof storage and is planted when new supplies of stock seed of a particular variety are desired. Since 1935, beet-sugar companies in curly top areas have cooperated in the production of elite and stock seed under the supervision of Department of Agriculture employees. This action was taken to insure the best possible reproduction of the varieties and to guard against contamination with inferior varieties. In addition, the cooperative effort extends to field trials whereby new and promising selections arising in the breeding investigations are compared with the curly top resistant varieties now in use.

The method of seed production most widely used in America is to plant the seed in localities favorable for growing sugar-beet seed in

late summer or early fall and allow the beets to grow in the field through the winter. Experience has indicated that there is no marked deterioration in yield or in sugar percentage by this method of reproducing varieties. The curly top resistance has, in general, remained the same, except, in some instances, severe curly top exposure in seed fields has eliminated susceptible plants, thus increasing to some degree the curly top resistance. The only difficulty yet encountered in the overwintering method of seed production has been increase in bolting tendency. This has been largely, or entirely, avoided by growing the seed in suitable areas with proper cultural methods to insure favorable conditions for every plant to produce seed. Special precautions have been taken to see that elite and stock seed are grown under the best-known conditions to avoid any possibility of deterioration of varieties.

## CLIMATIC INFLUENCES

An adequate supply of soil moisture is one of the first essentials for the successful production of sugar beets. In addition to an adequate

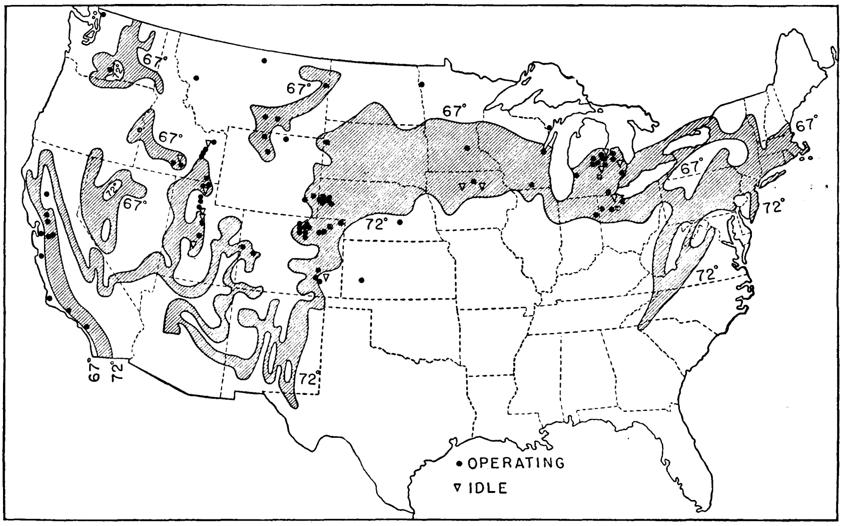


FIGURE 1.—Location of beet-sugar factories in the United States. The zone between the mean summer isotherms of 67° and 72° F. is shaded.

supply of moisture, either as rainfall or from irrigation, the sugar-beet crop is favored by a long growing season with moderate temperatures. The growing season should be at least 5 months long, and areas with an average temperature of about 70° F. for the summer months are generally best adapted to sugar-beet culture. This is indicated by the fact that nearly all beet-sugar factories are located between the isotherms of 67° and 72° F. mean summer temperature (May to September, inclusive), as shown by figure 1.

In the localities of the intermountain area where the sugar-beet crop appears to be permanently established, there is reasonable certainty of warm days and fairly cool nights during the growing season. Growth of the root continues as long as temperature and moisture

conditions are favorable and nutrients are available. Generally speaking, the longer this period, the higher the tonnage. As the sugar beet is grown for its sucrose content, it is important that warm and sunny days prevail during the latter part of the growing season, with progressively cooler nights, so that vegetative growth is slowed up and sucrose storage accelerated.

### SOIL REQUIREMENTS

Sugar beets can be grown on a great number of soil types and are not nearly so sensitive to the kind of soil in which they grow as many crops are. The soils in the intermountain area contain an abundance of soluble salts and usually have an alkaline reaction. For this reason waste lime from the beet-sugar factory is not in demand to correct soil acidity as it is in the humid beet-growing sections.

For successful production of the sugar-beet crop, the soil should have a good depth and a fairly high content of humus or organic matter. In the western soils the humus or organic matter is generally low and should be increased by a green-manure crop being plowed under at some place in the rotation and by adequate applications of barnyard manure.

### IRRIGATION SUPPLY

The selection of irrigated lands for sugar-beet growing necessitates a thorough examination of the irrigation-water supply. The sugar beet requires large quantities of water to produce a satisfactory yield. The supply of water available and also the regularity with which it may be obtained are both important considerations. Knowledge of how the water should be handled and also the water requirements of the crop are so critically important that these points are discussed in detail (see pp. 26–31).

## GROWING THE CROP

### SEEDBED PREPARATION

A properly prepared seedbed for sugar beets should be finely pulverized, compact, free from trash, moist, smooth, and level. Sugar-beet seed is properly planted when placed in moist soil about 1 inch beneath the surface in a seedbed containing sufficient moisture to germinate the seed and support the growth of the resulting plants. A firm seedbed makes planting to an even depth possible, assures even distribution of moisture, and affords good contact between the seed and the soil. A smooth and level seedbed makes it possible to plant all rows at the same depth and to obtain an even application of irrigation water without flooding any of the beets. Where soil might blow or where it crusts easily a fine clod mulch is preferable to a seedbed that is powdery in texture. However, coarse seedbeds or seedbeds with trash in them should be avoided as proper cultivation of the small beets is difficult under such conditions. If the seedbed lacks any one of the requirements enumerated above, there is much danger of a poor stand and a correspondingly low yield, whereas seed planted in a properly prepared seedbed is likely to produce a full stand and a good crop.

A number of common farm implements are used in seedbed prep-

aration. There is some variation in their use, but in general, it is necessary to use a plow, disk, spike-tooth harrow, and leveler. The roller or cultipacker and spring-tooth harrow are occasionally useful. They are especially useful when dry soil conditions prevail, which make compacting of the soil surface necessary, or when it is advisable to pulverize a cloddy soil surface to proper fineness.

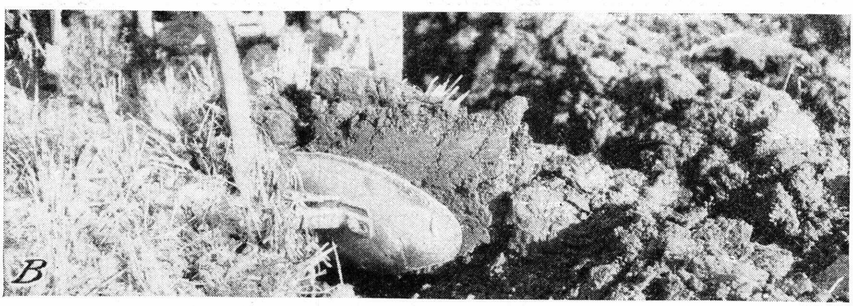

FIGURE 2.—*A*, Plowing with a two-way, single-bottom plow. Single- and two-bottom two-way plows are commonly used in areas where dead furrows interfere with the handling of irrigation water. *B*, Rear view of plow bottom, showing the grain stubble being properly turned under and the furrow slice pulverized as it is inverted.

## Plowing

Plowing is one of the essential operations in the preparation of a seedbed deep enough to supply ample feeding area for the beet. It brings about a thorough turning, stirring, pulverizing, and mixing of the surface soil to the desired depth. The design of plows both as to shape and materials has been developed to meet a wide variety of needs. Soil type, previous crop, and power available usually determine the shape, kind, and size of the plow used. The modern two-way plow is best for land that is to be irrigated, as it leaves no dead

furrows in the field. It is generally considered that a plow does its best work when operating at a depth one-half to three-fifths of its normal width. For a crop such as sugar beets at least a 14-inch plow is necessary for best results, and a 16- or 18-inch plow may be better.

Beet land should be plowed to a depth of 8 to 10 inches wherever previous practice and the soil type permit. Plowing to this depth forms a deep seedbed, destroys certain insects, gives more complete coverage of trash, and turns under some weed seeds to a depth that prevents their germination. However, land being prepared for sugar beets should not be plowed any deeper than it was plowed for previous crops. Beet seed is planted shallow; if it is planted in raw subsoil that has been thrown to the surface during plowing, considerable difficulty will follow during the early stages of growth. If shallow

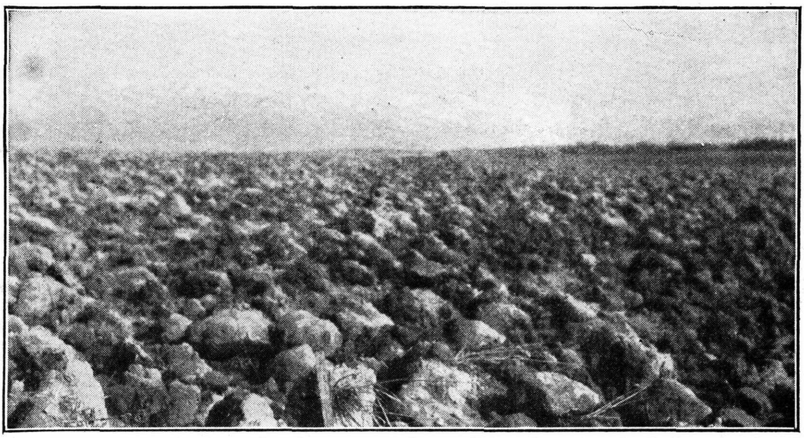

FIGURE 3.—A field plowed when very dry. The dry, hard clods remained in the field over winter. Unless sufficient moisture is applied to soften the clods, it is impossible to prepare a proper seedbed.

plowing has been the practice, the depth must be increased gradually, preferably by employing deep-planted crops such as potatoes in the rotation.

The heavier the soil, the greater should be the care and attention given to bringing it into perfect tilth. It is best to plow when the soil contains such an amount of moisture that the furrow slice will break and crumble when turned (fig. 2). Plowing the soil when it is dry breaks it into lumps that are difficult to reduce to a desirable tilth, whereas wet plowing may injure the structure of a soil by packing the furrow slice. In some areas the winter supply of moisture is insufficient to moisten the large clods, and it is difficult to prepare a satisfactory seedbed (fig. 3). Such dry lands should be irrigated before being plowed. Careful harrowing or disking as soon as the land is plowed will save much work later. Land can be left rougher over winter in areas where there is adequate winter moisture to soften the clods. Fall-plowed lands retain winter moisture well and require a minimum of working in the spring. With land thus prepared, a maximum of moisture is retained and timely planting is possible. Frequently spring plowing is done hastily and is accompanied by loss of moisture, which, in a dry spring, is a critical factor. As a rule. fall-plowed lands produce better yields.

### Harrowing

The spike-tooth harrow is one of the most useful implements in the preparation of the seedbed. It may be used to break clods, to form a soil mulch and prevent crusting, to assist in leveling the land, and to destroy small weeds. All spring-plowed land should be harrowed as soon as plowed, while the furrow slice is still in a friable condition and before dry clods have formed. One harrowing at this time accomplishes more than several later. In case of delayed planting the field should be harrowed as often as necessary to keep the surface free from crusts and weeds. All beet land should be harrowed after being leveled, and it is very helpful if the last harrowing can be performed at right angles to the direction of planting.

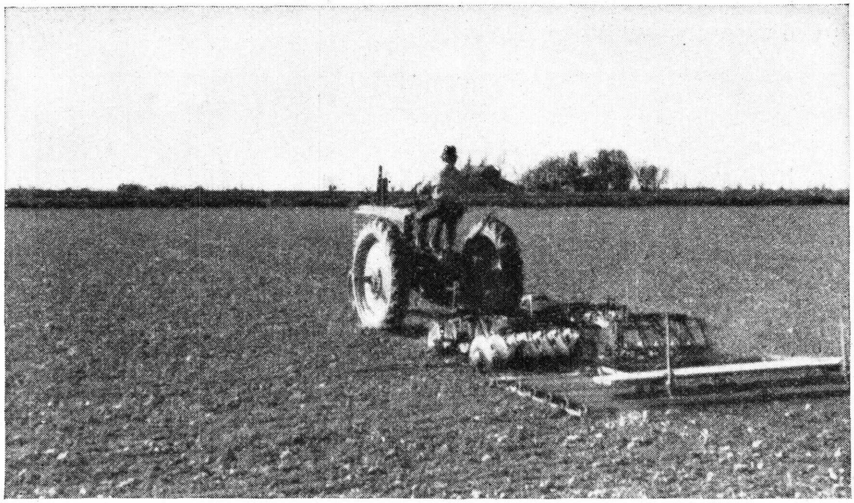

FIGURE 4.—Disking and harrowing fall-plowed land. This is generally the first step toward seedbed preparation in the spring. The tools shown above are also useful in preparing land that has been irrigated prior to planting.

### Disking, Rolling, and Leveling

Disking, following spring plowing, especially if organic matter is being plowed under, is often essential. The weighted disk, if set nearly straight, shatters the solid pieces of the furrow slice and stirs the soil so that the finer and looser material has an opportunity to move downward and complete the contact between the furrow slice and the subsoil. In areas or seasons where land is irrigated previous to being planted, it is also essential that the land be lightly disked following the irrigation. It is extremely difficult to fill in properly the irrigation corrugations with the spike-tooth harrow alone. On some fall-plowed lands that tend to settle firmly during the winter months, disking in the spring may be advantageous. Following disking and harrowing (fig. 4), certain types of rollers or the cultipacker may be used to give the seedbed the necessary firmness and to crush clods that may have been harrowed to the surface. Well-leveled ground is extremely important where beets are grown under irrigation. The box leveler (fig. 5) in common use in the irrigated areas is a very

efficient clod crusher and helps materially in firming the seedbed. The box leveler should be 16 to 20 feet long, as shorter ones do not properly fill in depressions. In some areas a land rail is very effec-

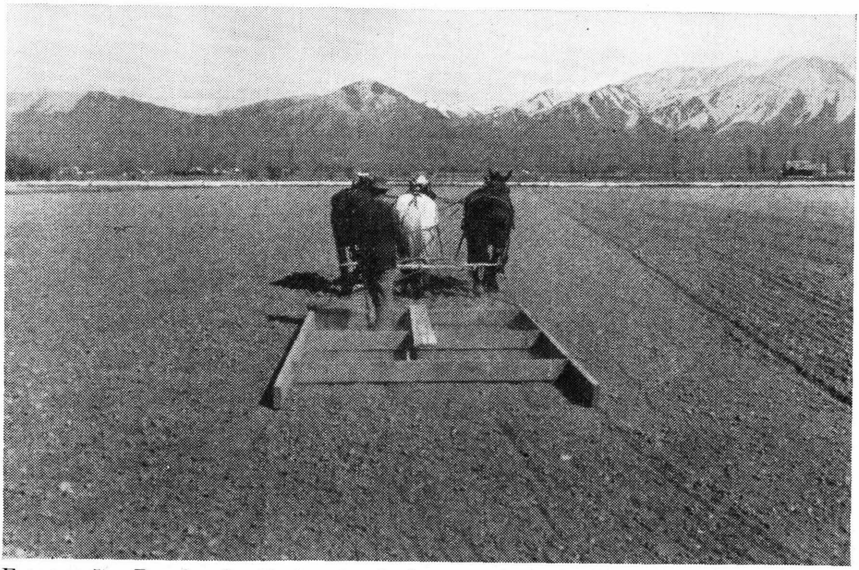

FIGURE 5.—Box leveler that not only levels ground for irrigation but is efficient in firming the seedbed and in pulverizing clods. Most land should be leveled twice, the second leveling being at right angles to the first.

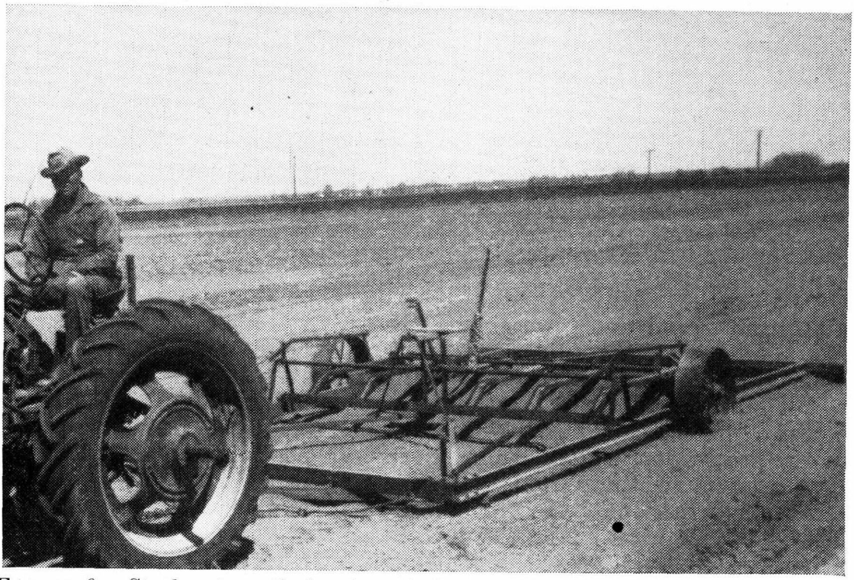

FIGURE 6.—Steel automatic leveler. This is used wherever there is extensive leveling to be done. The height of the grader-type blade is automatically controlled so as to slice off the high places and fill in the low ones.

tively used to accomplish the same purposes. A large steel automatic leveler (fig. 6) is coming rapidly into favor in some sections.

The complete leveling of land that is to be irrigated is so important that the expense for good leveling equipment is quickly repaid from increased acre yields. Following leveling, the land should then be lightly harrowed just prior to seeding.

## EQUIPMENT FOR PLANTING

Beet-seed drills are of various types, and each has its advantages and disadvantages. The efficiency varies under different conditions, and there is considerable divergence of opinion as to what type of drill is best. Any of the standard types do good work if adjusted properly and operated in an efficient manner.

Poor stands are often traceable to improper drill performance. Proper drill adjustment is easily accomplished by the grower; yet

FIGURE 7.—Beet drill equipped with shovels to make furrows while planting. Wide and narrow rows, as shown above, facilitate the making of furrows at planting time. The type shovel used on this drill is shown on the left in figure 20.

often this important operation receives very little attention. No drill should be used until it has been inspected carefully. This is most easily done by placing the drill on a level floor or plank where the height of each individual shoe and press wheel can be readily checked and measurements made to see that the shoes are adjusted for the proper row width. With a disk planter it is only necessary to set the bands to the desired depth on the disk.

In many seasons early irrigation may make all the difference between a good crop and a crop failure. In view of this fact, it is recommended that the drill be equipped with shovels (fig. 7) to make irrigation furrows while planting.

Drills are calibrated for different rates of seeding when they leave the factory. This calibration is for average-sized seed. Because seed varies in size, the amount of seed planted one year may vary rather widely from the amount planted another year. This makes it

important that the drill be checked each year for planting rate. A quick method that is approximately correct is to measure off half an acre of ground and weigh the quantity of seed used in planting the measured area. It is false economy to use too little seed.

A simple and more complete test for rate of seeding can be accomplished as follows: The drill should be jacked up so that the wheels clear the ground and the tongue propped up so that the drill sets level. With rows 20 inches apart there are 26,136 feet of row in an acre, and with 22-inch rows there are 23,760 feet of row in an acre. To expedite testing the drill, turn the drill wheel the equivalent number of times it would turn in covering one-tenth of an acre, or 2613.6 feet of row for 20-inch rows or 2,376 feet of row for 22-inch rows. Since 4 rows are being seeded if a 4-row drill is being used, 653 feet in the case of 20-inch rows and 594 feet in the case of 22-inch rows must be traveled by the drill for $\frac{1}{10}$-acre area, and if the drill wheel is 10 feet in circumference it must be revolved $\frac{653}{10}$ or 65.3 and $\frac{594}{10}$ or 59.4 times for 20- and 22-inch rows, respectively, to cover a $\frac{1}{10}$-acre area. Pans placed under each shoe catch the seed for weighing, and the uniformity of drilling for each shoe is easily determined. Ten times the total weight of seed caught in the pans will be the amount of seed the drill is planting per acre. If the total seed caught in the pans is 1.5 pounds, the drill is planting 15 pounds per acre, which under ordinary conditions should be the minimum amount.

The following general directions should be followed to obtain the best performance from the drill:

(1) Check the amount of seed planted by each drill spout separately.

(2) Check the depth of planting for each drill shoe separately and adjust to uniform depth of not less than 1 inch and not more than 1½ inches.

(3) Set the press wheels so that the soil will be properly firmed and the depth of the drill shoe will remain constant.

(4) Tighten the neck yoke and straps so that the drill tongue does not sway up and down or sideways.

(5) Check the setting of the marker device from both sides of the drill so that proper guess-row width is obtained.

(6) At each end of the field, check the amount of seed left in each seed can to see that all rows are being planted.

## FACTORS INFLUENCING STAND

Careful field counts have shown that, on an average, farmers have only 50 to 60 percent as many beets on each acre of land as would be obtained if there were no skips or gaps in the rows. The importance of stand is emphasized by the fact that the Utah Agricultural Experiment Station estimates that the average acre yield of sugar beets could be increased at least 4 tons if farmers obtained at least an 80-percent stand.

Factors that have a direct bearing on stand are: (1) Soil moisture; (2) depth of planting; (3) date of planting; (4) rate of planting; (5) soil crusts; (6) cultivation; and (7) thinning.

### Moisture

To obtain a good stand of sugar-beet seedlings an adequate supply of moisture near the surface of the soil is extremely important. In some sections, there is ample rainfall in early spring to germinate the seed, but the average grower puts too much reliance on rainfall as a source of soil moisture for germination and early growth. Much

better stands are obtained and generally better results accrue if the beets are irrigated promptly following planting or if the field has been irrigated prior to being planted. If water is to be applied soon after planting, irrigation furrows should be made during the planting operation (fig. 7). The question of moisture is more thoroughly discussed under the heading Irrigation (p. 26).

### Depth of Planting

The depth of planting is important. The best depth will vary with the season, but because it is impossible to predict the kind of weather for any great length of time ahead, the depth of planting should be one that will most nearly meet all conditions. Generally speaking, most growers plant deeper than necessary, with the result that ragged stands are obtained with many weak plants. One should seldom plant over 1½ inches deep, and if the seedbed has been properly prepared and moisture is as it should be, a 1-inch depth of planting will give good results. As a general rule earlier plantings may be planted shallower than later plantings.

### Date of Planting

For the best development of the crop, the sugar-beet plant should be given as long a season as possible in which to grow. Observations and experiments in the intermountain area indicate that the period in which the sugar-beet crop may be planted extends from the middle of March to the middle of May, but it has been demonstrated that extremely early planting or extremely late planting should be avoided. Because the seasons vary so widely it is impossible to give the best planting date for all years, but demonstrations in commercial fields and also experimental plots show that in general higher yields are obtained if plantings are made before April 15.

The sugar beet is more frost resistant than most cultivated crops grown in this area. However, with extremely early plantings, frost injury may be severe in certain years, especially if the freezing occurs when the plants are just coming through the ground. Plantings made too early may also suffer from prolonged periods of cold weather even though temperatures do not get below freezing.

If fields are foul with weeds, certain modification of the normal planting date is sometimes desirable. Although generally it pays to plant beets when the soil and air temperatures have become warm enough for germination and growth, under certain conditions it pays to delay planting until the surface weed seeds have sprouted. Land infested with wild oats furnishes the best example of the advantage of delaying planting. At best, the growing of sugar beets on land infested with wild oats is not likely to produce a large crop, because this weed furnishes very strong competition for the young beets. This practice of delayed planting must be looked upon as a general control measure for field improvement.

If planting is delayed for any reason, the ground should be irrigated before it is planted. This is especially important when the planting has been delayed for the purpose of weed control, as the added moisture will cause more of the weed seeds to sprout.

### Rate of Planting

The initial stand is thinned drastically, only one beet being left at about 12-inch intervals in the row. If uniform spacing is to be

obtained, the initial stand must have one or more sturdy seedlings every 2 inches in the row.

Generally speaking, it is unwise to plant less than 15 pounds per acre when a drill that plants the seed in a continuous row is used. The planting of this amount of seed is made necessary by the fact that at seeding time one can never determine what conditions may arise to decrease the percentage of germination or weaken and destroy the seedlings.

Although most drills now in common use drop the seed in a continuous row there are on the market hill-drop and single-seed-drop drills. The latter two types use considerably less seed. One of the recent advances in farm machinery is the improvement of drills which effectively plant a single seed ball at a place. Abundant trials are being conducted with these new machines and with segmented seed (seed balls that are so sheared that usually each portion contains only one germ) to determine their effectiveness and whether such plantings can permit machine blocking or blocking with a long-handled hoe to give adequate thinning of the stand. (See page 18.)

## Soil Crust

Crusting of the soil is one of the very common causes of failure to obtain a good stand of sugar beets. If dashing rain or hail is followed by hot sunshine a crust is likely to form. The more rapid the drying, the harder the crust. Some sandy soils do not crust, but most of the soils in the beet-growing areas of the intermountain area have a tendency to crust, and the beet grower must be equipped to meet the situation in the event that weather conditions are such as to cause crust formation. During the early stages of beet-seed germination the young plant makes its growth wholly from the small reserve food supply in the seed. After a time, the reserve food is exhausted, and unless the seedling promptly reaches the light, where it can manufacture its own food, it dies or is so weakened as to fall an easy prey to soil fungi. It is, therefore, necessary to adopt all possible measures to prevent crust formation or to break the crust after it does form, so that the young seedlings can come promptly into the light.

Many methods are used to break crusts, and the method to be selected depends on conditions and the tools at hand. Rolling is one of the best methods (fig. 8), but sometimes in the spring there is a series of hard rains a few days apart and if a roller is used to break the crust each time it may pack the subsurface too tightly and damage the crop. If a crust forms immediately after planting, it can be satisfactorily broken by harrowing at right angles to the direction of the rows. However, the ordinary harrow should never be used if the beet seedlings have already grown into the crust. This machine breaks most of the crust, but in doing so it moves some of the soil crust laterally and shears off the beet seedlings. Tests have been conducted in which the spike-tooth harrow destroyed approximately half of the seedlings, whereas the roller killed practically none of them.

Special equipment (fig. 9) has been built for breaking soil crusts. It is very effective and does not unduly damage the seedlings. Of light construction and low first cost, it is used as an attachment to the ordinary beet cultivator. The crust is broken without causing any side movement.

## Wind Damage

In many parts of the intermountain area drying winds occur during the spring months, and this fact must be taken into consideration if a grower expects to obtain a satisfactory yield of beets. The first serious problem confronting the grower is one of supplying water to the crops and securing its retention in the soil during the critical

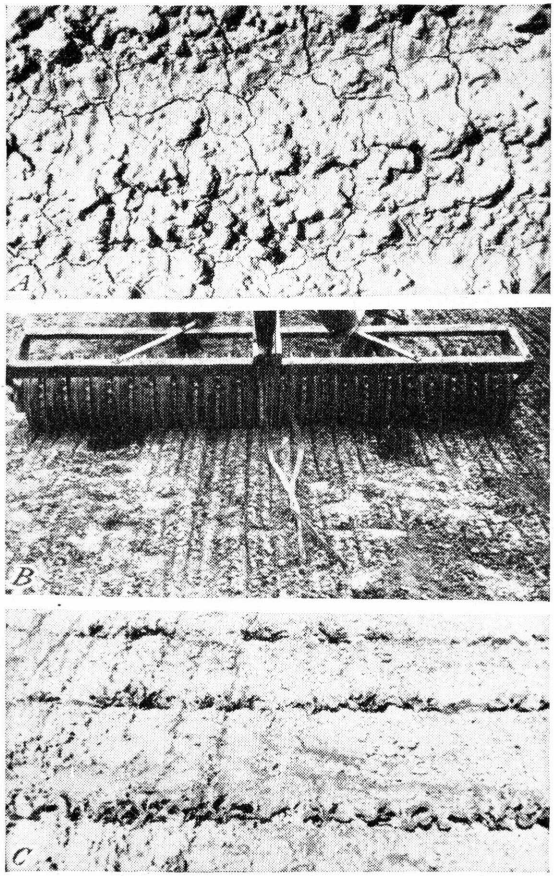


FIGURE 8.—Timely breaking of crusts is very important. *A*, Heavy soil crust formed just as the young beet seedlings were beginning to emerge. *B*, Western land roller. This machine breaks the crust without injuring the stand. *C*, Excellent stand obtained by use of roller where otherwise there might have been a complete failure.

period of germination and early growth. After a rainy period high winds often bring about rapid drying of the soil and the formation of crusts, especially on heavy lands. The crust must be broken by suitable tools.

A type of wind injury known as sand blast is serious in certain sections with excessively sandy soils. Small areas in a field or the entire field may be subject to serious wind injury while beets are small. Wind damage is difficult to control, but may be partially controlled by such special treatment as top dressing with manure and

leaving the surface soil rather cloddy. Planting the rows at right angles to that of the prevailing winds prevents the injury to some extent. This practice is especially helpful if shovels are attached to the drill and furrows are made at planting time.

## BLOCKING AND THINNING

The sugar-beet seed ball contains from one to five, or even more, true seeds (fig. 10). In planting, the farmer should realize that it is the small true seed that produces the young plant. Hence, with ordinary commercial seed, even the planting of one seed ball in a place gives rise to clumps of plants. Furthermore, because an excess of seed is used to insure a good initial stand, it is necessary to block and to thin the seedlings to the proper spacing. These operations need to be done before there is too much competition among the plants.

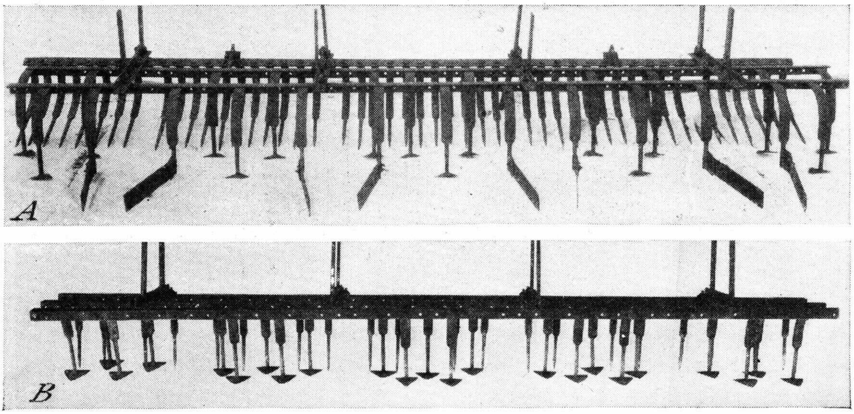

FIGURE 9.—Special cultivator attachment for shallow cultivation, crust breaking, and mulching the soil surface: *A*, The front bar has been reversed so that the teeth are in the position used when breaking crusts; *B*, tools assembled for weeding and mulching.

It is rather difficult to specify just when beets should be thinned. Time of thinning is influenced by growing conditions and also by the presence of seedling diseases or insect pests. Generally speaking, blocking and also thinning, if blocking and thinning are done as one operation, should begin when the beets have 4 true leaves and should be completed by the time the beets have 8 to 10 leaves. There is experimental evidence to indicate that, in general, early thinning produces better yields than later thinning.

In soils infested with wireworm or cutworm or if seedling diseases are present, thinning to singles should be delayed for a week to 10 days later than usual. This delayed thinning will be less detrimental if the beets can be blocked at the normal time, either with long-handled hoes (fig. 11) or by mechanical blocking.

If blocking is done by hand, the grower should make clear to the laborers employed that deep cuts with the hoe will not be tolerated. This type of blocking leaves trenches in which the singled beets that hang only by their threadlike roots will dry and die. Good stands are not obtained by this type of blocking. In this respect, mechanical blocking has the advantage of leaving the soil in a more normal position and causing less exposure to the beet root. Mechanical blocking

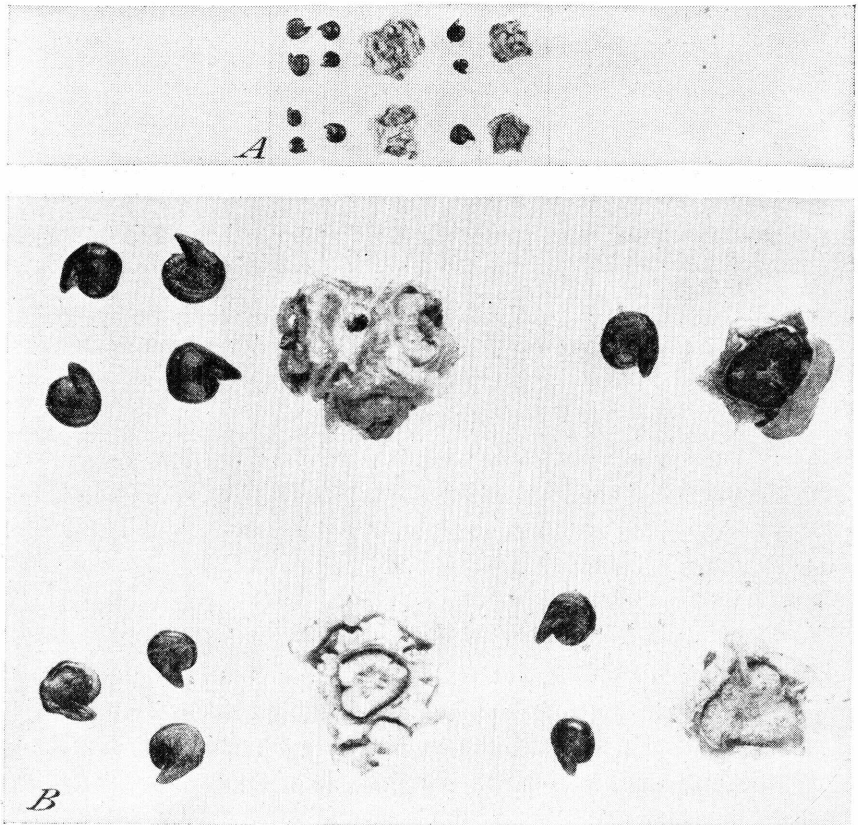


FIGURE 10.—Sugar-beet seed balls and true seeds. The seed ball contains from one to several true seeds. *A*, Natural size, and *B*, enlarged.

FIGURE 11.—Blocking and thinning sugar beets. Three workers make one complete thinning unit. One man blocks with a long-handled 6- to 8-inch hoe, and the other two reduce the blocks to singles.

has not come into so wide practice in Utah and Idaho as in some areas of California and Colorado. This is due principally to two circumstances—the comparatively small acreage grown by each individual farmer and the fact that the labor situation has never been a serious problem.

Much has been said about leaving the largest beets at thinning time. There is little doubt about this advice being sound if seedling diseases are present, because it is important to leave healthy seedlings. However, it is also important to leave the individual beet that will be least disturbed by the blocking and thinning procedure. There can be no question that the vigorous, healthy beets in a clump are often disturbed and injured in thinning. Hence they become more stunted in subsequent growth than smaller beets that might be left undisturbed at thinning time.

Surveys conducted by the United States Department of Agriculture have shown that there is an average loss of 21.4 percent in stand during thinning and the cultivations that immediately precede and follow thinning. This indicates that the most profitable way a grower could spend his time during beet thinning is to give it his personal supervision. It has been estimated that with 12 to 15 thinners at work, it is worth $50 to $60 a day for a grower to be in the field checking on both spacing and quality of work done.

## SPACING

High profitable yields depend greatly on uniformity of stands. Skips in the stand are wasteful whether the beets are closely or widely spaced at thinning time. The exact number of sugar beets to grow per acre varies somewhat for different areas and different fields. There is also a very definite varietal response to spacing. Some varieties require close spacing, whereas others produce a higher yield with wide spacing. The customary spacing of plants at 12-inch intervals for 20- or 22-inch rows may, with adequate water supply, be advantageously lessened to 10-inch intervals or even to 8-inch. The particular pattern achieved is probably less important than maintenance of an adequate plant population uniformly distributed. Evidence from experiments in Utah and Idaho indicates that, with lighter soils that are fairly high in fertility but do not produce heavy leaf growth, closer spacing than 12 inches between plants is desirable. However, for very fertile soil, which promotes excessively heavy leaf growth, spacings wider than 12 inches should be chosen.

A general rule governing width of spacing is hard to formulate. There is, however, one general criterion that gives a fairly reliable indication as to the spacing that should be used. It can be safely said that the spacing should be close enough and the stand uniform enough so that by August 1 the leaves will so completely cover the ground that no bare soil is visible. The majority of the commercial fields now producing beets have large enough skips in the rows so that bare sections of rows are visible throughout the entire season. Where this condition exists there is no question but that the farmer is losing in yield. Once a farmer has learned whether beets do best on his farm closely spaced, i. e., about 8 inches apart, corresponding to about 150 beets per 100 feet of row, or more widely spaced, i. e., 12 to 14 inches apart, corresponding to 100 to 90 beets per 100 feet of

row, considerable effort should be exerted to make the spacing as uniform as possible. In most cases, having stands uniform and free

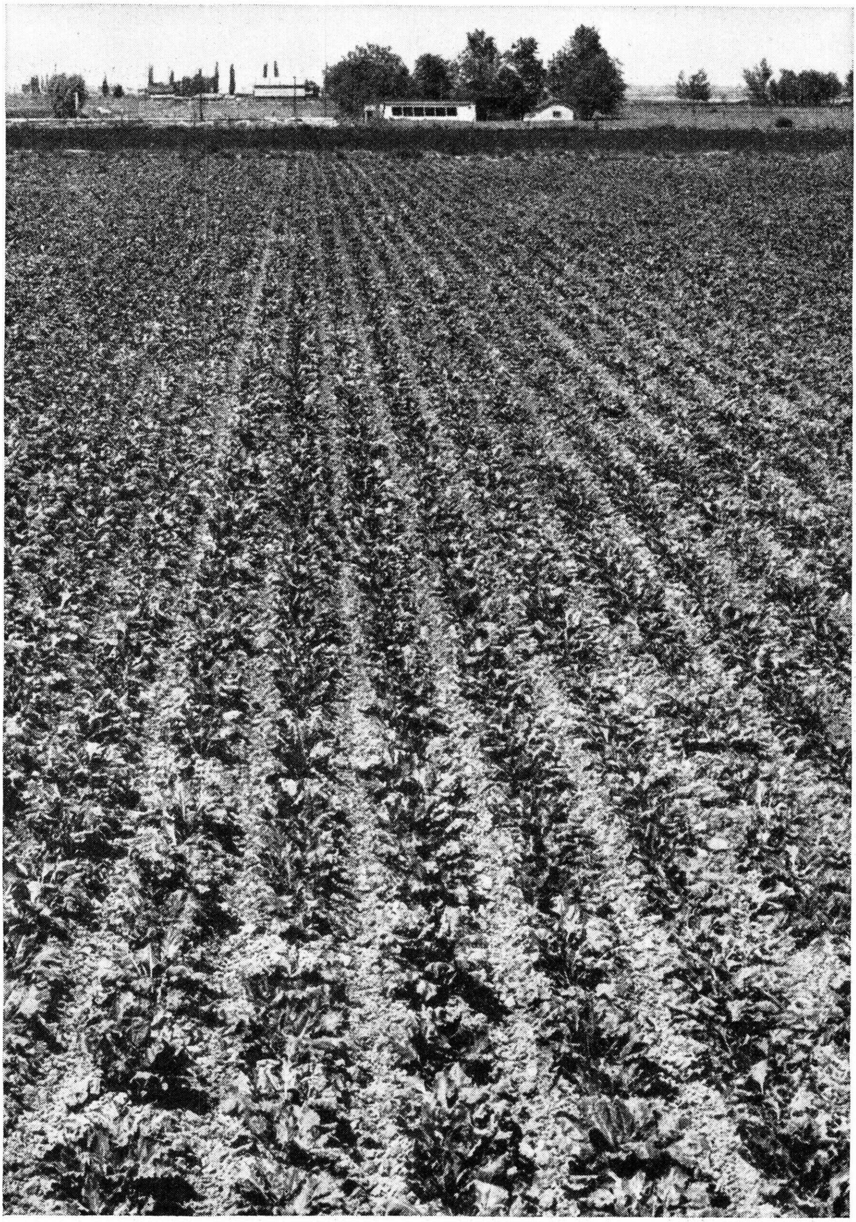

FIGURE 12.—A good stand of beets, proper cultivation, and freedom from weeds; three of the essentials for raising a good crop of sugar beets.

from skips is more important than having any definite number of beets per acre within the limits of 100 to 150 beets per 100 feet of row (figs. 12 and 13). In case there are skips in the initial stand, it is

important to vary spacing accordingly. Beets spaced close together adjacent to each end of a 3- or 4-foot skip, and in rows adjacent to the skip, will to some extent utilize the extra space and reduce the loss that would otherwise result.


FIGURE 13.—Careful thinning and proper cultivation: *A*, Beets thinned May 23—note that dirt has not been hoed away from roots; *B*, the same beets just 23 days later, on June 15, following two irrigations and three cultivations. The third irrigation was given June 18. Average yield at harvest was better than 30 tons per acre.

It should be repeated that close supervision of thinning will probably bring higher returns for the extra time spent in the field than an equal amount of time spent at any other period.

## MECHANICAL BLOCKING

In areas where mechanical blocking is substituted for hand blocking, the usual type of cross-blocking machine is an ordinary beet cultivator. The cultivator is equipped with suitable tools spaced

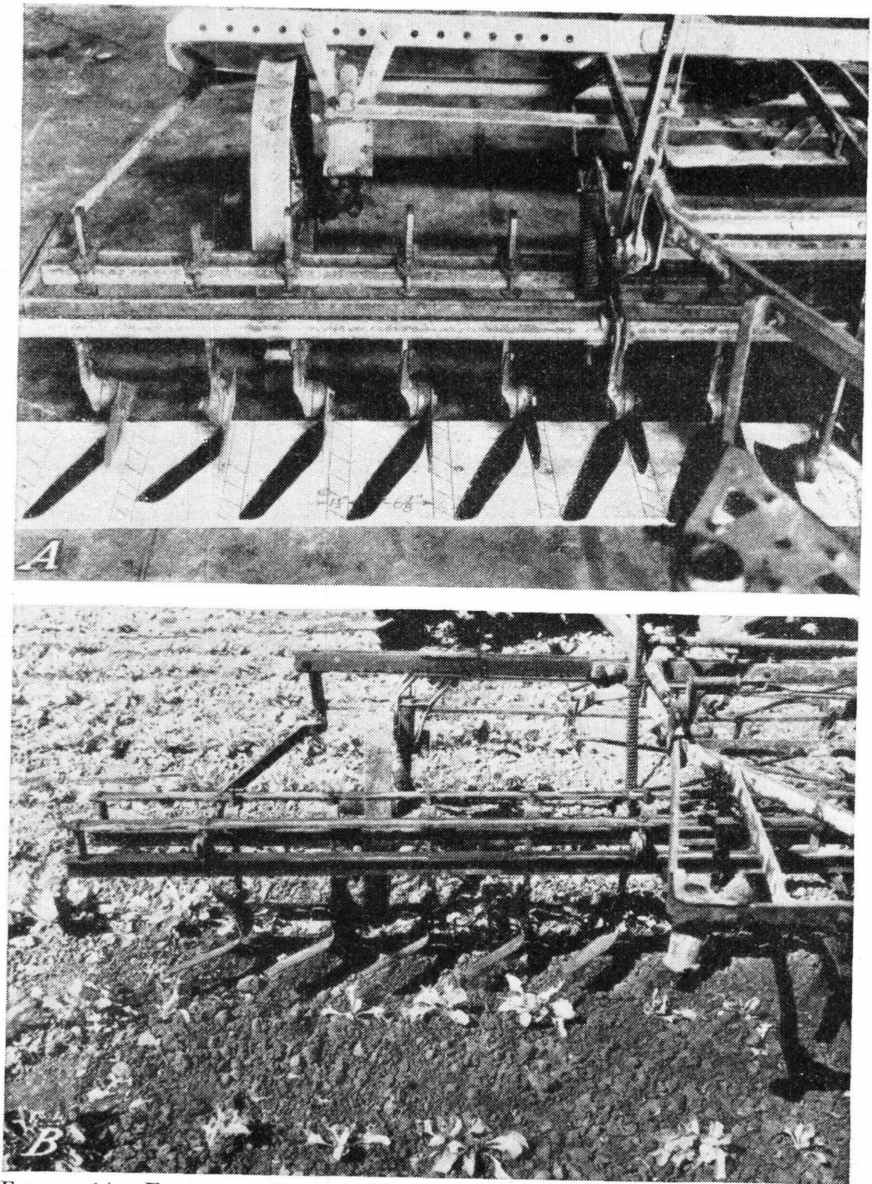

FIGURE 14.—Equipment for cross blocking sugar beets. *A*, Adjustable weeder knives that are particularly adapted to use in cross blocking as they can be set flat so as to prevent soil movement. Combinations of disks and knives or duckfoot shovels are also frequently used. *B*, Cross-blocking knives raised out of the ground, showing unblocked beets ahead and a blocked row, with the cut-out beets removed, just behind the knives. (Photograph by S. W. McBirney, Division of Agricultural Engineering, University Farm, Davis, Calif.)

so that blocks of beets of the required size and spacing are left undisturbed when the machine is drawn at right angles to the beet rows. Markers like those used on a beet drill are necessary. The type of soil largely determines the kind of tool used. These tools generally consist of knives, duckfoot shovels, and disks used either alone or in suitable combination (fig. 14).

Recently the development of single-seed droppxr drills (fig. 15) has stimulated renewed interest in the possibilities of elimination of much

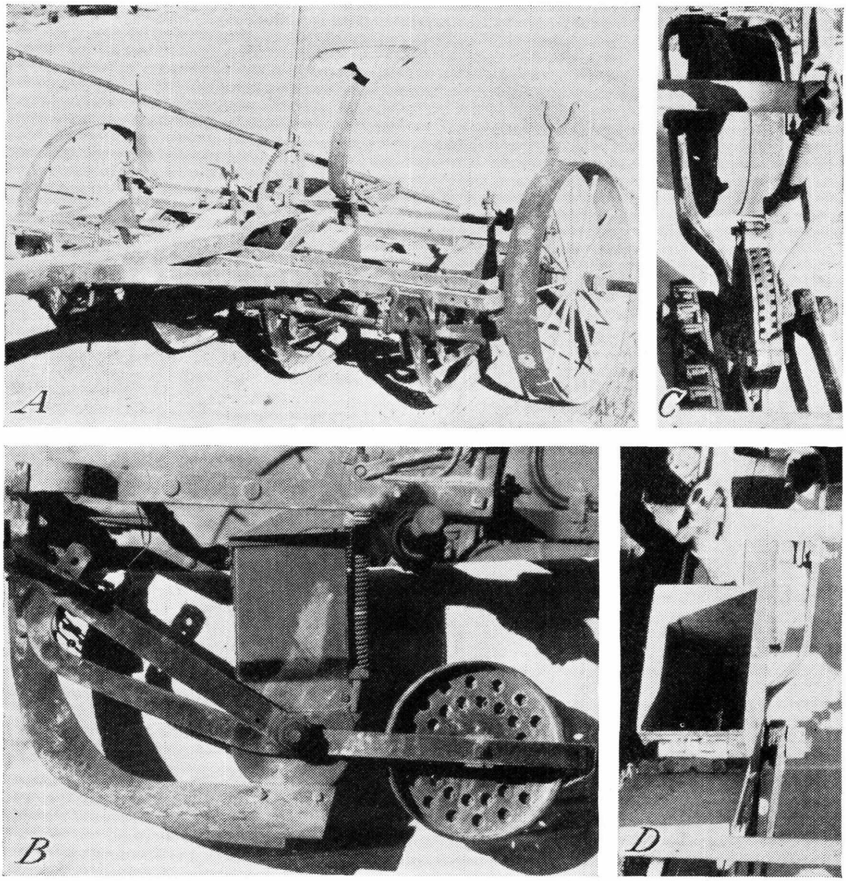

FIGURE 15.—Drill with special single-seed dropping attachments: *A*, A common type of drill converted to single-seed dropper by replacement of usual feed mechanism with special single-seed pick-up device; *B*, detail of shoe, seed can, and press-wheel assembly; *C*, looking down in seed can; and *D*, disk in bottom of can for carrying single-seed balls.

of the hand thinning. By use of the single-seed dropper type of drills, 4 to 6 pounds of seed are sown per acre. It has been demonstrated that good stands can be obtained when this small amount of seed is distributed uniformly, as is possible with this new type drill, and where special care is taken in seedbed preparation. The resulting thin but uniform stands can then be mechanically cross blocked to advantage. Many of the resulting blocks contain singles, and a large

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proportion of the remaining blocks contain no more than 2 beets per block.

Recent spacing work has shown that the yield from doubles left in blocks 20 inches apart in the row was equal to singles 10 inches apart in the row. This fact indicates that with proper control of initial stands and careful blocking with the hoe there is the possibility of eliminating much of the hand labor of thinning, especially on large acreages.

In much of Utah and in some of the Idaho districts, the average acreage of sugar beets per farm is less than 10 acres. On these farms mechanical blocking and the omission of the usual thinning operations will not likely prove extremely advantageous. However, on some of the larger acreages, especially in case of labor shortage, the possibilities of mechanical blocking and reduction of hand labor should be given consideration.

## CULTIVATION

Weed destruction is the primary purpose of cultivation, but the method and degree of cultivation affect the quality and yield of the crop. Special soil conditions may make timely cultivation important for other reasons than weed control. If the soil is waterlogged, cultivation is a positive benefit in drying and aerating the soil. Heavy soils benefit most from cultivation for these purposes. Such cultivation is most likely to be needed when the crop is young, and at that time and for that purpose it should be deep and close to the rows. Later cultivations should be shallow, as deep cultivation prunes the roots and interferes with utilization of the soil near the surface where most of the quickly available plant food is located.

Sugar beets require several cultivations during the season. At least one of these should be performed before thinning, another shortly after thinning, and others at intervals as needed until the leaves cover the rows. Whereas early cultivations may be for the purpose of aerating and drying the surface soil, later cultivations may conserve moisture by checking runoff and facilitating penetration into the soil. The soil mulch in itself has little effect in preventing the escape of water, but the cultivation that creates the mulch destroys weeds that would compete with beets for the available moisture and plant-food supply. Weeds are most easily killed when they are small, and timely cultivations will do much to reduce the labor of hand hoeing.

Different tools are used for the various cultivations (fig. 16). The first cultivation should be done with the knives or disks set close to the row and a duckfoot run sufficiently deep in the middle of the row to push the dirt back against the beets. If the disks are used alone, the small beets are left on a narrow ridge that dries through rapidly, and the young beets are injured. Close cultivation with knives covers more plants but does not throw the dirt away from the small beets as do the disks when used alone. Special cultivating and mulching equipment is now available that can be fastened to any modern four-row cultivator (figs. 9 and 17). This equipment has the advantage of wider adjustment and effective weed control with very little movement of soil. Early cultivations for the purpose of aerating and

drying out the surface soil are usually performed with either the knife-edge bull tongues or diamond points. These tools are not practical for the later shallow cultivations. Furrowers or irrigation shovels are used for making the furrows for irrigation. Choice of the type of shovel used depends on the soil type and the size of the beets. Press furrowers with the bull-tongue attachment can be successfully

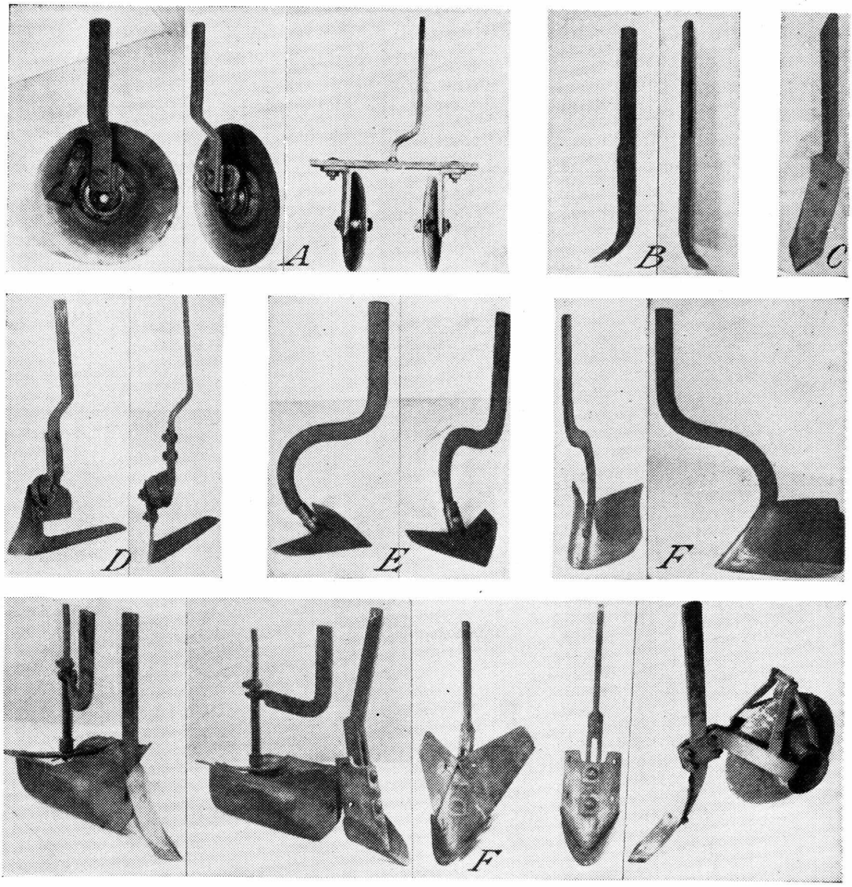


FIGURE 16.—Beet-cultivator tools: *A*, Two types of adjustable disks; *B*, knife-edged diamond points; *C*, shank and steel, or bull tongue; *D*, adjustable knives; *E*, duckfoot shovels; *F*, types of available irrigation furrowers or shovels. (Note the range of adaptability of some of the various types.)

used on very small beets when it is necessary to furrow and irrigate beets before thinning (figs. 16 and 18). The proper adjustment of the cultivator tools is as important as the selection of proper tools. Tools can be set to run flat or pointed down so that they will dig in. However, if the tools are nosed down too much they tend to throw too much dirt on the rows. Choice of angle at which the tools are set depends largely on the soil type and size of the beets.

## IRRIGATION

In the intermountain area no farmer should attempt the growing of sugar beets unless he is assured an adequate and continuous supply of water during the entire growing season. Beets should be irrigated whenever the leaves turn dark green or begin to wilt in midday and do not quickly recover at night. This is true whether the beets have only a few leaves or are nearing maturity. There are still many farmers who believe that withholding water early in the season until the small beets suffer, "drives the roots down to water," and thus produces a larger beet. This theory has been disproved many times in field tests. Young beets must not be allowed to suffer for water. Roots do not penetrate dry soil, and it is therefore important that the root zone be kept continually moist. In many seasons early irrigation

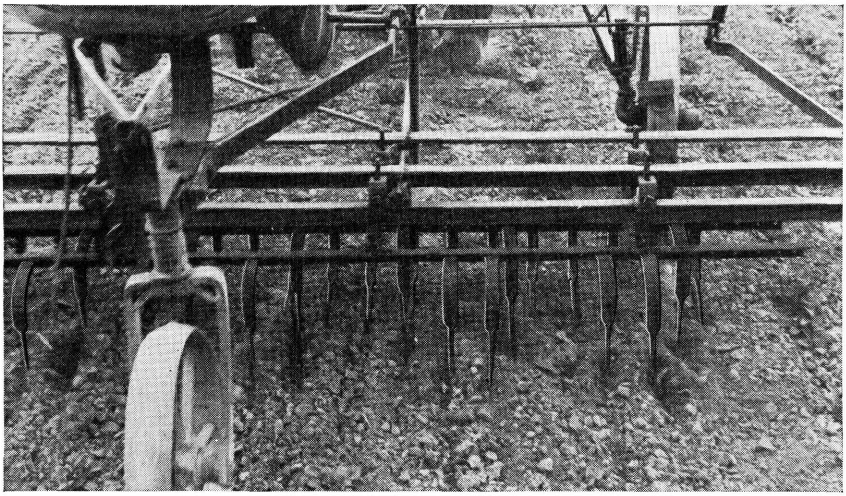

FIGURE 17.—Cultivating small beets just prior to thinning with the special weeding and mulching equipment shown in figure 9. The front teeth have been left in a sloping position similar to that in which they are used for breaking crusts.

may make all the difference between a good crop and a crop failure (fig. 18).

Feeding roots on a sugar beet growing under favorable conditions extend from the surface soil to a depth of 5 or 6 feet (fig. 19). Lack of moisture in either the surface or subsoil cuts down the feeding area of the beet and consequently retards its growth. In early season it is important that the surface soil should not be allowed to dry out enough to lose connection with the moisture in the subsoil. Light irrigations are generally sufficient to maintain this connection. In mid and late season it is equally important that the subsoil should not be allowed to dry out. Heavier irrigations, which will wet the soil to greater depth, are then necessary. At no time, however, is it advisable to allow the soil to become so saturated that a waterlogged condition results.

In some localities it is necessary to irrigate before or immediately after planting. In irrigating before planting, furrows are made 20 to 40 inches apart, depending on the type of land, and the field is then

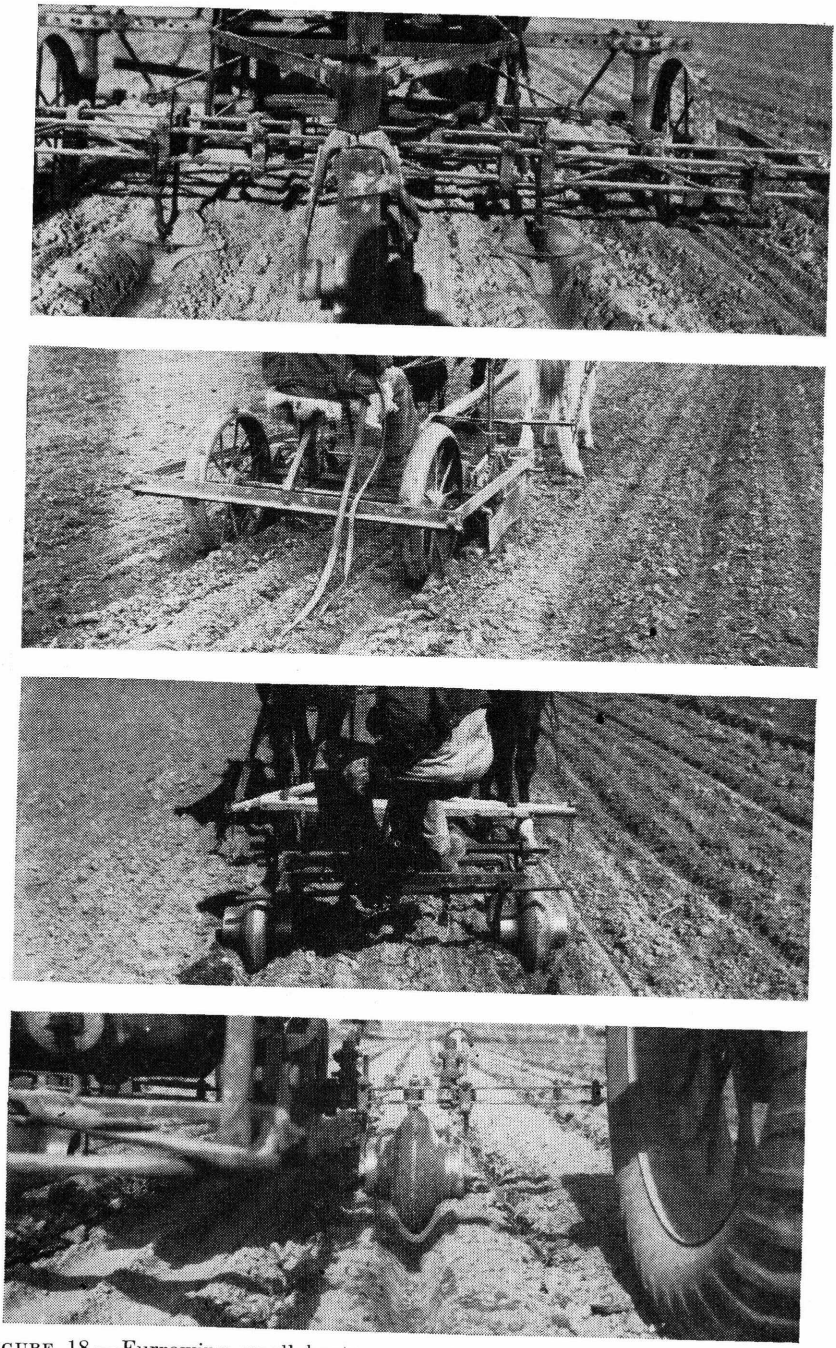

FIGURE 18.—Furrowing small beets preparatory to the first irrigation. Proper tools make the job easy and efficient. The equipment shown above makes clean, smooth furrows and does not cover the small beets. (Photograph from the Amalgamated Sugar Co., Ogden, Utah.)

irrigated. As soon as the land can be worked, it is smoothed down and the seed planted. Where irrigation follows planting, it is advisable to attach corrugator shovels (fig. 20) to the drill so that the fur-

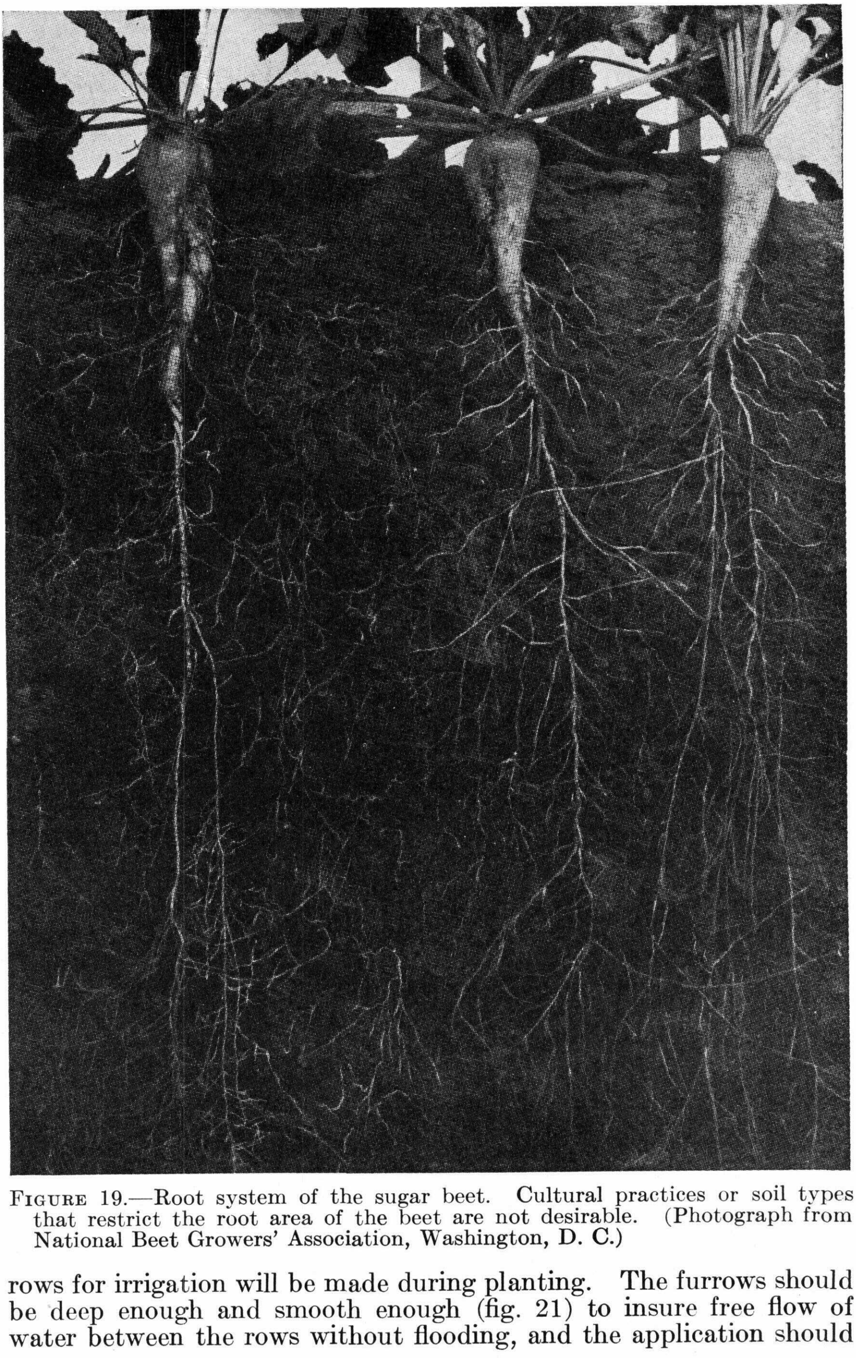

FIGURE 19.—Root system of the sugar beet. Cultural practices or soil types that restrict the root area of the beet are not desirable. (Photograph from National Beet Growers' Association, Washington, D. C.)

rows for irrigation will be made during planting. The furrows should be deep enough and smooth enough (fig. 21) to insure free flow of water between the rows without flooding, and the application should

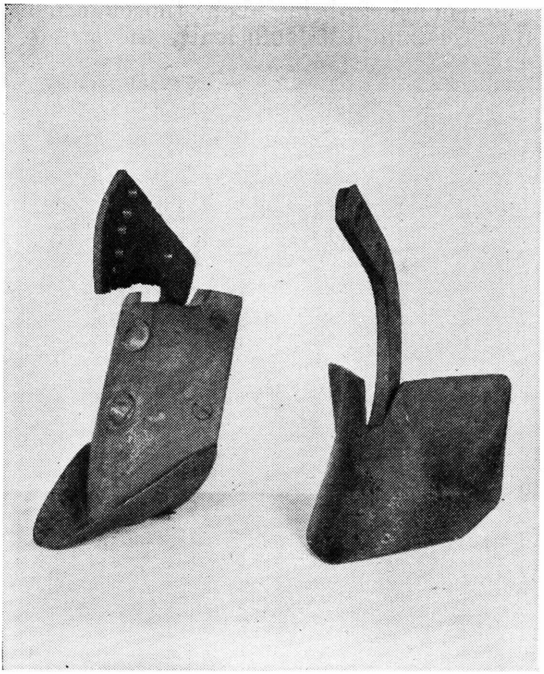

FIGURE 20.—Two types of shovels that may be used on the drill to make furrows at planting time.

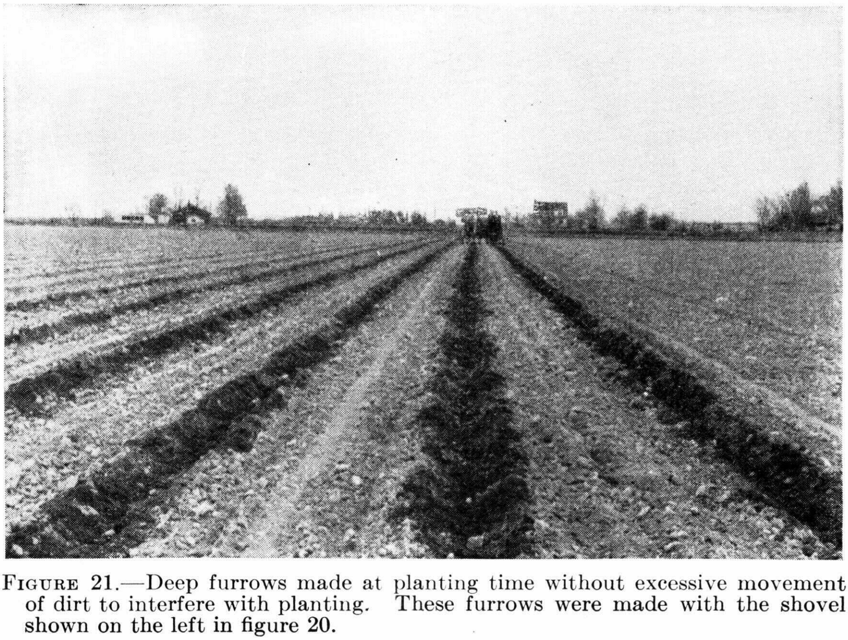

FIGURE 21.—Deep furrows made at planting time without excessive movement of dirt to interfere with planting. These furrows were made with the shovel shown on the left in figure 20.

be continued long enough to bring about thorough moistening of the seed. As soon as the land dries sufficiently the surface mulch should

FIGURE 22.—Irrigating sugar beets. This irrigation was applied a short time after thinning. The water was distributed evenly, and there was no flooding nor excessive soil erosion.

be restored, so that there will be no crust to hinder the emergence of the young beet seedling.

In many seasons, if the land has been fall-plowed so that the seedbed can be prepared by merely harrowing and leveling in the spring,

there will be sufficient moisture in the soil so that irrigation will not be necessary until after the cultivation that follows thinning. It should always be remembered, however, that it is better to irrigate a little too early than a little too late.

The amount of water to apply with each irrigation and the frequency of irrigations depend largely on soil type. A farmer who has handled his land for several years knows how to irrigate in order to get the water deep enough into the soil to connect with the subsoil moisture. In general, once irrigation of the growing crop is started it will be necessary to apply approximately 2 to 3 inches of water every 10- to 14-day period. Care should be exercised in distributing the water so that excessive soil erosion will be prevented, and flooding should be avoided at all times (fig. 22).

If the beets are kept growing throughout the growing season they may be watered later than formerly was thought desirable and still mature normally. Beets that do not suffer for water up to harvest time go to the factory in much better condition for slicing and represent more nearly a normal crop than those that have dried badly.

## SOIL MANAGEMENT

The soils of the intermountain area, suitable for sugar-beet production, have considerable variation in texture, structure, and content of alkali. Beets do best on fertile, well-drained loam, silt loam, and clay loam soils. Light loams and sandy loams may produce beets of good quality but usually will not yield a profitable tonnage per acre, except in cases where such soils are high in fertility.

The shape of the beet root is influenced by soil structure. If the soil is too shallow or the water table is high, root penetration is limited, and the roots will be ill-shaped. Compact impervious soils or, on the other hand, gravelly soils that do not contain much fine material are not suitable for sugar beets. The farmer should avoid serious problems in soil management by not using these soils.

The problems of soil management that must be considered with soils adapted for sugar beets are (1) drainage and alkali, (2) crop rotation, (3) preparation of alfalfa fields for sugar beets, and (4) manures and fertilizers.

### DRAINAGE AND ALKALI

Excessive moisture in the soil is not favorable to sugar beets. The young plants on such soils are frequently damaged by root rots commonly called "black root" (see p. 23). High water tables also reduce the feeding area and cause sprangled roots instead of the normal straight taproot. In much of the intermountain area, lands that were too wet for successful cultivation have been converted into productive lands when this difficulty has been corrected by drainage. Under certain conditions drainage is also valuable as an aid in alkali control.

There are various ways of draining lands, but only two are of consequence. Fortunately, large areas of land in the intermountain area in need of drainage may have their excess water drawn off, or at least largely controlled, by means of deep, open ditches at intervals of from half a mile to 2 or 3 miles. This work is done by machinery, and often beet-sugar companies are prepared to offer some sort of

help in this respect when a group of farmers is willing to undertake part of the operation. In other places soil conditions are such that tile drains are recommended. The initial expense is greater for tile drainage, but the maintenance is less if the system is properly installed. The drainage system must be so installed as to lower the water table until it is from 3 to 4 feet below the surface of the soil.

Sugar beets are somewhat more resistant to alkali than are many of the other farm crops. However, in the seedling stage they are severely damaged by strong alkali, and their ability to resist alkali should not be overestimated. When land contains just enough accumulated soluble salts to cause injury to potatoes, to grain crops, and to truck crops, sugar beets will frequently thrive. If seepage is present, however, there is great danger of alkali accumulating to the toxic point. The most successful means of preventing this and of removing excess salts already present is to install some dependable system of drainage.

## CROP ROTATION

Crop rotation requires the growing of different crops in a planned recurring succession on the same land. In contrast to the continuous growing of a single crop on the same land, or to haphazard cropping of the land without plan, crop rotation generally has many advantages. Foremost, perhaps, is the provision made in a good rotation for maintaining or improving the fertility of the soil. Among the outstanding advantages of crop rotation from a soil-fertility standpoint are the following: (1) It helps keep soil in a suitable physical condition; (2) it helps to maintain the supply of organic matter and nitrogen in the soil; (3) it provides by a planned farming program a practical means of utilizing farm manure and fertilizer; (4) it keeps a larger portion of the soil occupied with crops and thus reduces loss of fertility by leaching and erosion; (5) it changes the location of the feeding range of roots; (6) it counteracts the possible development of toxic substances, pests, and diseases; and (7) it is one of the most effective means of keeping land free from weeds, which compete with the growing crop for both moisture and available plant food. It has been demonstrated, however, that crop rotation alone is not absolute insurance that soil fertility will be maintained.

Proper handling of leguminous crops and the use of manures and fertilizers are also important. The rational use of manures (both as green manure and barnyard manure) and commercial fertilizer in conjunction with crop rotation will prevent soil depletion much more effectively than rotation alone.

The details of arrangement and kind of crops in a rotation will vary with the region, but the basic principles of good rotations differ but little. Crop rotation under irrigation agriculture should attempt to accomplish the following:

(1) Permit the growing of approximately the same acreage of each crop each year.
(2) Provide for growing at least one cash crop.
(3) Include a hay crop.
(4) Include a sod-forming crop to last 3 to 5 years.
(5) Include a legume.
(6) Alternate tilled and nontilled crops.
(7) Alternate shallow-rooted and deep-rooted crops.

(8) Arrange crops in such a way as to distribute the seasonal requirements of labor, equipment, irrigation water, and personal supervision.
(9) Follow such a sequence of crops as will maintain good soil sanitation and at the same time be convenient.
(10) Provide feed and pasturage so that livestock may be kept.
(11) Facilitate the application of manure to the crop that gives the most profitable response.
(12) Facilitate making use of all byproducts in order to avoid waste.
(13) Provide at least one green-manure crop to be plowed under during the rotation period.

It has been found that where three or more crops are grown in rotation, the arrangement of the crop sequences often has an important effect on the yield of certain crops. Experimental results are available which show that where sugar beets are grown in a 3-year rotation with oats and potatoes, the yield of sugar beets is definitely depressed following oats but is satisfactory following potatoes. On the other hand, potato yields have been satisfactorily maintained following oats. Thus, if oats or similar cereals are included in a farm program that also includes potatoes and sugar beets, the proper arrangement of the crop sequence is highly important. Leguminous crops, such as alfalfa, clover, and more recently soybeans grown as a green-manure crop, are commonly included in the farm program in the irrigated areas of Utah and Idaho. Cropping programs including sugar beets, potatoes, grain, and 3 to 4 years of alfalfa are characteristic of the practices found on many irrigation projects. Ordinarily the yields of sugar beets immediately following alfalfa are low, but relatively satisfactory yields of potatoes can be expected from potatoes immediately following alfalfa. Sugar beets following potatoes in such a rotation have shown large increases over the alfalfa-sugar-beet-potato sequence. Often such results as this have confused farmers and led them to question the benefits to be derived from including alfalfa in the planting program. In areas in Utah and Idaho where potatoes are not a part of the farm program, it may be necessary to follow either grain or alfalfa with beets. In this case manuring and early fall plowing are frequently of more than usual importance. A more complete discussion of the cultural practices to be followed in an alfalfa-sugar-beet rotation is given in the section entitled "Preparation of Alfalfa Fields for Sugar Beets" (p. 34).

Definite recommendations for all localities as to the exact crop sequence to use, or even the various crops to use in the rotation, cannot be given. Several that seem to have wide adaptation in Utah and Idaho are outlined in table 1.

TABLE 1.—*Rotations suitable for use with sugar beets*

| Rotation | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First | Second | Third | Fourth | Fifth | Sixth | Seventh | Eighth, ninth, tenth |
| A | Red clover | Potatoes | Sugar beets. | Grain [1] | Red clover | | | |
| B | Alfalfa | do | do | Beans or peas. | Potatoes | Sugar beets. | Grain [1] | Alfalfa. |
| C | do | Beans or peas | do | Grain [1] | Alfalfa | Alfalfa | Alfalfa | |
| D | Sweetclover | Truck crops | do | do [1] | | | | |

[1] Legume crop sown with grain crop.

## PREPARATION OF ALFALFA FIELDS FOR SUGAR BEETS

In the irrigated areas alfalfa and clover are the crops commonly grown, and much of the land devoted to them is later planted to sugar beets. Both alfalfa and clover are excellent crops to grow in rotation with sugar beets, but inasmuch as alfalfa or clover roots present a problem in planting and cultural care of the beet crop, it is often advisable to grow potatoes or grain preceding the beet crop. If, however, beets are to follow alfalfa or clover there are two methods of plowing that have been found to be generally satisfactory. The surest method of getting a 100-percent kill of alfalfa is to plow shallow (not more than 4 inches deep) early enough in the season to insure

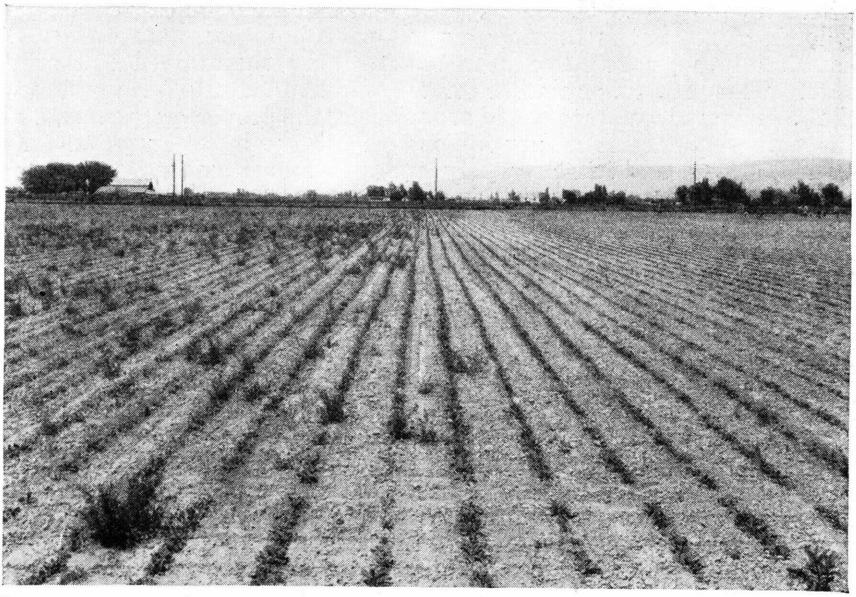

FIGURE 23.—Alfalfa sod plowed late in the fall. Note troublesome surviving plants on the left. Deep plowing of the third crop of alfalfa as a green manure or crowning and replowing if a green-manure crop is not being plowed under, completely kills such plants, as is shown on the right.

thorough drying of the crowns. The land is then plowed 8 to 10 inches late in the fall, and the short stub roots that remain near the surface do not materially interfere with planting or cultivating. An even better method from the standpoint of maintaining soil fertility, and one that if properly followed also gives a satisfactory kill of alfalfa, is to plow while the crop is in a growing condition. The most satisfactory practice is to plow under the third crop just prior to the time it would normally be cut for hay. The ground is still warm, and if sufficient moisture is supplied, the green-manure crop will rot quickly. In this manner all the roots and crowns are destroyed, and plant food is added for the following crop. This method is not successful, however, if plowing is delayed until the cool temperatures of fall prevent complete decomposition (fig. 23). Sod lands should not be spring-plowed for sugar beets.

## MANURES AND FERTILIZERS

It has been found that the rotation of crops alone is not an insurance against soil exhaustion, even when alfalfa or similar leguminous crops are included in the cropping program, and that good rotations alone will not maintain crop production indefinitely without the addition of supplementary plant-food elements. Crop rotation, supplemented by the use of barnyard manure, green manures, and commercial fertilizer, forms the backbone of a permanent irrigation agriculture. Farm manure has been found to be the most effective agency in maintaining and improving the productivity of land. However, manure is rarely available in sufficient amounts to fulfill the

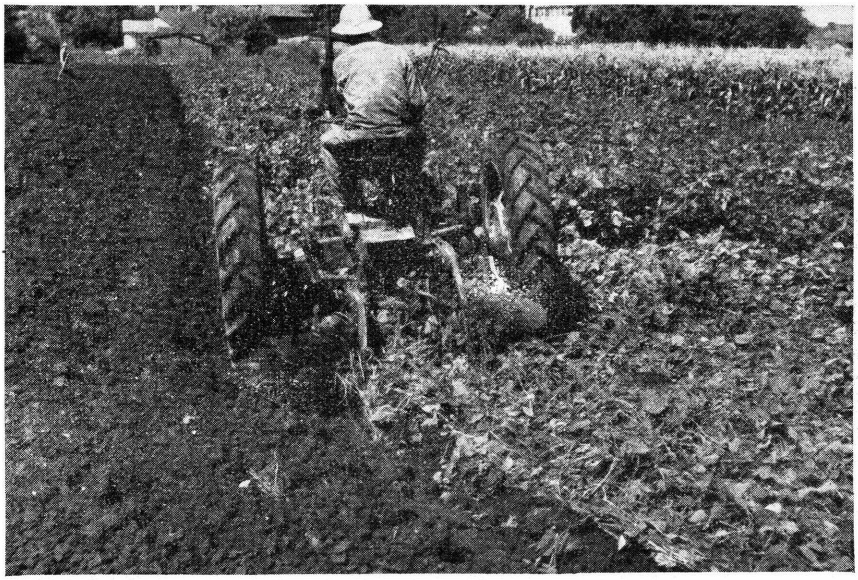

FIGURE 24.—Plowing under soybeans as a green manure. Note the following principles of good green-manuring practice: (1) Complete coverage of the plant material; (2) succulent plant growth and optimum soil moisture for decomposition; and (3) early plowing so that temperatures are favorable to bacterial activity.

requirements. Often, therefore, it is necessary for the farmer to provide other means of maintaining the productivity of the soil, such as a soybean crop grown after a grain or other early harvested crop (fig. 24). A promising solution of the problem, which is coming into greater use, is the inclusion in the rotation of such leguminous crops as alfalfa or sweetclover, and pasturing one season during the rotation. It has been found that by pasturing alfalfa or sweetclover, production costs are reduced, the net returns per acre are greater than those obtained when the hay is marketed, and subsequent crop yields are stimulated to an extent often equaling such intensive treatments as the inclusion of alfalfa and applications of farm manure in the same rotation. If pasturing of the alfalfa, prior to breaking it up, is not feasible, the most satisfactory practice will be to plow under the green-manure crop in late summer so that complete decomposition can take place prior to the planting of the subsequent crop.

In the main, western soils are deficient in organic matter. In addi-

tion to this, all intertilled crops such as sugar beets deplete the soil of organic matter. For this reason it is essential that steps be taken to increase the organic content of the soil. The chief function of farm manure and sod crops is to supply organic matter, which is the basis for bacterial activity by which plant-food elements in the soil are changed to usable forms. Most of the soils in Utah and Idaho are high in plant foods, but these often occur in a form not readily available to the plant. One of the important effects of both farm manure and green manures is to make plant food available from the soil reserves. In addition to the effect of organic matter on food reserves, organic matter creates a condition of medium porosity in the soil and greatly increases its water-holding capacity.

FIGURE 25.—Manuring just prior to fall-plowing land for beets.

### Farm Manure

The use of farm manure in connection with the sugar-beet crop is a common practice. When it is available, the manner of application and the quantity to use are both important considerations. It is estimated that the average farmer does not get more than a quarter or a third of the potential value of the manure available. The economic possibility of preventing much of this loss has been conclusively demonstrated both experimentally and practically. When it is possible to haul fresh manure directly to the field, this practice is advised, as excessive losses by leaching and fermentation are thereby prevented. Turning manure under in the fall is preferred, but it can profitably be spread on plowed ground or even on the snow during the winter months. In this case, it should then be worked into the soil with a disk as early as possible in the spring. If the land is not fall-plowed, it is still a good practice to apply the manure in the fall or during the winter. Manure stored for spring application should be piled in a large, square, compact pile or accumulated under sheds

where it is kept thoroughly packed and damp by the animals. It should then be applied at the earliest possible time in the spring.

It is often found that greater benefit is derived by manuring some cultivated crop, such as corn, potatoes, or truck crops, which immediately precedes the sugar-beet crop, than by applying the manure directly to the sugar-beet crop. It may also be added after peas or beans or to the legume sod previous to breaking. Application of manure in the spring just prior to the beet crop may not only interfere with both efficient cultivation and irrigation but also may delay the growth of the beets.

Applications of from 6 to 10 tons of manure per acre have given more economic results for all ordinary crops than have either extremely

FIGURE 26.—Broadcasting treble-superphosphate prior to planting sugar beets. The grain drill shown has a convenient fertilizer attachment which makes it possible to place the phosphate 2 to 3 inches deep in the soil.

light or extremely heavy applications. Manure should be scattered as soon as it is hauled. Making small piles to be scattered as another operation increases labor and also losses from the leaching of the manure. Manure spreaders are much more efficient than hand labor in obtaining even distribution (fig. 25).

### Phosphate Fertilizer

Experimental work with commercial fertilizers in the intermountain irrigated area has not reached the stage where definite recommendations for the entire area can be made. It has been very definitely shown that there are many areas in Utah and Idaho where marked response from the use of superphosphate may be expected. Farm manure is relatively low in phosphoric acid, and in many cases the addition of phosphate fertilizer has greatly increased the returns. In areas where phosphate fertilizers give response, the most common method of application is to broadcast from 100 to 150 pounds of treble-superphosphate by using a grain drill with a fertilizer attachment, prior to planting (fig. 26). Nearly all sugar-beet seed drills

now in use in Utah and Idaho have fertilizer attachments, and an additional application of from 50 to 100 pounds of phosphate is sown with the seed at planting time.

The above-outlined procedure is thought to be much safer than the use of larger amounts of fertilizer with the seed. In many cases, larger amounts have been applied with little or no damage, but, under certain soil and moisture conditions, as little as 125 pounds per acre drilled in the furrow with the seed may cause considerable retardation of growth or injury.

## HARVESTING THE CROP

In order that the crop may make all the tonnage possible and store as much sugar in the roots as conditions will permit, the harvest should be deferred as long as it is safe to do so without danger of having the crop, or part of the crop, frozen in the ground. The actual beginning of the sugar-beet harvest is determined by the purchasing company's announcement of readiness to receive the beets. This date is governed in part by the stage of sugar storage reached by the crop as determined by field sampling. Sometimes at the beginning, when permission is first given to harvest, so many growers start harvesting that it is necessary to close the receiving dumps for a few days. If too many beets are delivered while the weather is still comparatively warm, there is danger of loss by deterioration if the roots are piled. Although developments of mechanization in hauling and in dumping facilities have been most pronounced, it is expected that present hand methods used in harvesting will be further modified. Mechanical loaders have come into favor with some of the large operators in Idaho. All of the improvements in harvesting equipment have shortened the period necessary for harvest. With the shorter harvest period, it is possible to delay the harvest and allow the beets to mature more fully and to increase in sucrose content.

In harvesting, the sugar beets are lifted with a specially designed beet lifter that loosens the beet roots and lifts them slightly, breaking off the taproot fairly deep in the ground. Having thus been lifted, the beets are ready for the topper, who uses a knife equipped with a hook on the end to pull and top the beet. Careful topping is important. The beets should be topped in a manner that meets the requirements of the receiving company. After being topped, the roots are either thrown in windrows or piles. Six or eight beet rows are thrown into one windrow, depending on the preference of the grower or crew. From these windrows or piles, the beets are loaded into trucks for delivery to the receiving station or factory. Loading is done either by hand, with forks, or (see above) by a beet-loading machine. If the roots are put in piles or a beet-loading machine is used, it is necessary to first clear off and make smooth the area where the beets will be windrowed or piled. This is done with a suitable V-shaped sled.

Sugar beets should be hauled as soon as practical after they are dug and topped. If, for any reason, the roots have to be left in the field after being topped for any considerable length of time, they should be covered with tops to prevent loss of weight by drying or freezing. Frozen beets should never be piled but should be milled as soon as possible.

A number of mechanical pullers and plows have been developed in the past, some of which pull, top, and load the beets in one operation. These machines are not as yet in general use.

## SUGAR-BEET BYPRODUCTS

Byproducts of the beet industry can be divided into two classes: (1) Those that result from harvesting operations on the farm, which include the tops and crowns, and (2) those produced at the factory, which include the molasses, wet pulp, and dry pulp.

### TOPS AND CROWNS

Fresh beet tops at topping time have a very high feeding value. On the average they will weigh 75 to 80 percent of the beet tonnage at topping, i. e., a 15-ton yield of beets will produce 11 to 13 tons of fresh tops. With higher beet yields the acre yield of tops frequently closely approximates the root yield. The tops from a 15-ton yield of beets contain about 1½ tons of dry matter and nearly a ton of digestible nutrients. This is about equal to the digestible nutrients in 1.3 tons of barley or 2 tons of alfalfa hay. From lamb-feeding experiments at the Belle Fourche (S. Dak.) Field Station, it was calculated that beet tops were worth $1.36 per ton of beets produced, i. e., when 15 tons of sugar-beet roots per acre were raised, the tops had a potential value of $20.40 per acre. Comparable results have been reported by the Wyoming Agricultural Experiment Station at Worland, Wyo. Experiments reported by the Colorado Agricultural Experiment Station place a value of from $16 to $20 per acre on the feed value of tops.

Beet tops lose much of their feeding value if left lying too long in the field. They should be harvested and stored in the best way to conserve as much of the feeding value as possible, for they usually provide the cheapest available source of fattening feed.

There are several ways to utilize tops, and probably no one way is best under all conditions. The all-too-common practice of leaving them scattered over the field is to be discouraged. A farmer would not think of leaving his alfalfa hay spread out in the field subject to bleaching by the sun and damage by rain. If he did, the alfalfa would be worth little more than straw. He cannot afford to lose a large part of the feeding value of the beet tops by handling them in this way. Pastured beet tops usually have less than one-half the value of tops that are cured carefully and then properly stacked to conserve feeding value. If tops are pastured during a rainy season, there is not only a considerable waste of feed but there is also the detrimental effect of packing the soil when wet, which often results in a cloddy condition that is difficult to overcome in the spring. Pasturing the tops in the field in the fall has the further disadvantage of interfering with fall plowing.

If, however, tops must be pastured in the field, they should be fed soon after topping, and dry alfalfa hay should be fed as a supplement. Cattle or lambs should be hand-fed a small amount of the beet tops along with plenty of hay a few days before they are put on beet-top pasture or the high mineral content of the beet crowns will tend to cause digestive disturbances.

Gathering the tops soon after topping into small piles about the size of an inverted washtub (fig. 27) in the field helps to cure them and conserve their feeding value. The tops may then be profitably handled in one of two ways. They can be hauled and stacked with alternate layers of straw or alfalfa hay, or they can be hauled from the piles in the field and fed to the animals in the corral.

When feeding beet tops to fatten steers a few ordinary precautions should be kept in mind. Beet tops are a relatively high mineral-carrying feed. The salts present in crowns are cathartic and tend to cause scours unless the quantity of tops fed is restricted. The Colorado Experiment Station reports that the addition of one-tenth of a

FIGURE 27.—Beet tops gathered in piles in the field. These tops were gathered while the ground was being fall-plowed and were hauled to the feed lot as needed.

pound of lime ($CaO_2$) to the daily feed is very effective in the control of scours.

Silage can be made from fresh tops, and, if they are handled properly, an excellent feed results. In siloing beet tops care must be taken to free the tops from all dirt. This can best be done by gathering and hauling the tops immediately after topping. Fresh green tops may be siloed either in a trench silo or by stacking them above ground much in the same way that pea-vine silage is handled. Choice as to whether tops should be fed as silage or dried in small piles and fed as dried tops is largely dependent on weather conditions at harvest time. The Colorado Experiment Station has shown that clean tops are of greatest value in the form of silage, but that dirty tops (tops with dirt adhering to them due to adverse weather) are best fed as dried tops, so that stock can shake much of the soil from the tops while eating them.

## BEET PULP AND MOLASSES

Beet pulp is a byproduct that remains after the beet roots have been sliced and the sugar has been extracted. Most of the sugar manufacturers sell this byproduct to the farmers and livestock feeders in the vicinity of the factory. The pulp contains little protein or phosphorus but is fairly rich in carbohydrates and may be fed in the fresh, dried, siloed, or pressed form. The greater portion of the pulp in the irrigated areas is stored in silos, although some factories press and dry pulp.

Pulp is most profitably fed in connection with feeds that supply protein, phosphorus, and additional energy material.

Molasses from beet-sugar manufacture is a good carbohydrate feed that may be added to other feeds, such as pulp, beet tops, legume hay, or grain. It contains about 58 percent of digestible nutrients and has a high value when limited quantities are included in a ration. The most common use of beet molasses is to feed it mixed with ground alfalfa hay or beet pulp.

Beet pulp and beet molasses are both excellent carbonaceous feeds, but both of them are very deficient in phosphorus. Wet pulp contains only about 1/100 of 1 percent of this mineral and beet molasses contains only 2/100 of 1 percent. Feeding demonstrations conducted under direction of the Utah State Experiment Station demonstrated that the addition of 1/10 pound of steamed bonemeal per head to the daily ration increased the average gain during the 129-day fattening period from 193.2 pounds for the check lot to 336.3 pounds for the lot receiving the bonemeal. It is, therefore, recommended that steamed bonemeal, as a source of phosphorus, be added to the daily feed, especially where sugar-beet byproducts form a large portion of the daily ration.

The data presented in table 2 show the comparative value of various feeds used to fatten livestock in the intermountain area. It is evident that sugar-beet byproducts rank high as stock feed. As an illustration of the use of sugar-beet byproducts in fattening steers, a series of rations is shown in table 3.

During the past few years steers from sugar-beet growing States have repeatedly topped the Chicago market, and sugar-beet byproducts have been an important part of the fattening ration.

TABLE 2.—*Comparative values of various feeds*

| Feeds | Digestible nutrients in 1 ton of feed | Estimated cost per ton | Cost per 100 pounds of digestible nutrients |
|---|---|---|---|
| | *Pounds* | | |
| Wet sugar-beet pulp | 178 | $1.00 | $0.63 |
| Alfalfa hay | 1,006 | 9.00 | .90 |
| Dried molasses beet pulp | 1,486 | 18.00 | 1.21 |
| Beet molasses [1] | 1,198 | 14.00 | 1.17 |
| Barley | 1,580 | 20.00 | 1.27 |
| Corn silage | 374 | 5.00 | 1.34 |
| Cottonseed cake (43 percent protein) | 1,510 | 34.00 | 2.25 |
| Beet tops from 15-ton yield of beets (with an estimated loss of 35 percent in feeding value) | [2] 1,684 | [2] 7.50 | .45 |

[1] A high protein molasses is frequently referred to in literature dealing with the Colorado area. It is molasses from the Johnstown plant where the barium process is used. Such molasses is lower than ordinary beet molasses in carbohydrates and carries about twice as much protein. Little if any of the high protein molasses is used in the area covered by this bulletin.

[2] Acre basis; green-top weight estimated as about 75 percent of the yield of sugar-beet roots. Digestible nutrients calculated from data by Morrison, F. B. Feeds and Feeding. Ed. 20, 1936, p. 966.

TABLE 3.—*Cattle-fattening rations*[1] *including sugar-beet byproducts*

[Data prepared in the Bureau of Animal Industry]

| Initial weight of animal | Wet beet pulp | Dried molasses beet pulp | Beet top silage | Cured beet tops | Beet molasses | Barley | Alfalfa hay | Cotton-seed meal |
|---|---|---|---|---|---|---|---|---|
| *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* |
| | 25 | ------ | ------ | 6 | 2 | 4 | 4 | 1 |
| 450 | ------ | 3 | ------ | ------ | 2 | 5 | 6 | 1 |
| | ------ | ------ | 15 | 4 | ------ | 5 | 5 | 1 |
| | 30 | ------ | ------ | 6 | ------ | 6 | 5 | 1 |
| 650 | ------ | 4 | ------ | ------ | 2 | 8 | 8 | 1 |
| | ------ | ------ | 25 | ------ | ------ | 9 | 6 | 1 |
| | 40 | ------ | ------ | 6 | ------ | 11 | 3 | 1 |
| 850 | ------ | 5 | ------ | 5 | 3 | 9 | 5 | 1 |
| | ------ | ------ | 35 | ------ | ------ | 12 | 6 | 1.5 |
| | 60 | ------ | ------ | 8 | 3 | 7 | 6 | 1 |
| 1,050 | ------ | 6 | ------ | ------ | 3 | 10 | 10 | 1.5 |
| | ------ | ------ | 45 | ------ | ------ | 10 | 8 | 1.5 |
| | 80 | ------ | ------ | ------ | ------ | 12 | 8 | 1.5 |

[1] These rations represent the average quantities to be fed daily during the entire fattening period and are intended to serve as a guide in feeding operations. It is a good plan to feed 1/10 pound of sterilized steamed bonemeal per head daily in order to guard against phosphorus deficiency. At times when the cost of molasses exceeds the cost of barley or when molasses is needed for the production of war materials, as at present, it is advisable to replace molasses with barley or other grain in cattle-fattening rations.

## CURLY TOP

The curly top disease was recognized and described as early as 1897. From that date until 1934, when the United States Department of Agriculture introduced a variety resistant to curly top, practical control measures were not available and disease outbreaks took heavy toll from the sugar-beet growing districts west of the Rocky Mountains.

Curly top is caused by a virus that is carried by the beet leafhopper (*Eutettix tenellus* (Bak.)). The earliest symptoms of the disease apparent on affected plants is an inward rolling of the lower and outer margins of the youngest leaves. The lower surface of the leaves becomes roughened and shows conspicuous vein swellings. The vein swellings vary in individual plants from those in which every veinlet is irregularly swollen to those which show only scattered, inconspicuous, rounded swellings. The diseased leaves are dark green, thick, crisp, and brittle.

The roots of sugar beets affected with the disease also show marked symptoms. The curly top virus causes death of the lateral rootlets. The beet then, in an effort to reestablish itself, sends out a large number of new lateral rootlets. This gives the beet root a hairy or woolly appearance, and when the beet is pulled from loose soil a mass of soil frequently adheres to the roots. A cross section of a diseased root often shows dark concentric rings alternating with light circular areas. A longitudinal section shows the dark discoloration extending lengthwise through the beet.

### CONTROL OF CURLY TOP

In 1934 the United States Department of Agriculture released the curly top resistant variety U. S. 1. Since that time other resistant varieties that are greatly improved over the one first introduced have been developed by plant-breeding investigations.

Beginning in 1935, the work of breeding new and improved curly top resistant varieties was strengthened by closer cooperation with

the beet-sugar companies operating in the curly top area. At this time, the Curly Top Resistance Breeding Committee was established, the membership consisting of representatives of the various beet-sugar companies operating in the curly top affected Western States. This committee, through contribution of funds, has facilitated the testing of new and promising varieties and has made possible greater extension of the breeding program than would have been possible with the Federal funds available. The committee, by its activities with respect to the production of elite and stock seed, has served to bring the varieties arising in the Government breeding work promptly into use.

Resistance of the sugar beet to curly top increases rapidly with the size and age of the plant (see p. 5). In unfavorable dry springs, beet leafhoppers may migrate from desert breeding areas into the sugar-beet fields early and infect the sugar-beet plants with curly top while they are still very small. Under these conditions, the extent of the leafhopper invasion may determine to a large degree the amount of damage the beet crop will suffer.

The prevalence and distribution of weed hosts on which the beet leafhopper feeds and breeds determine to a large degree the size of overwintered leafhopper populations in the breeding grounds and the rate of development and size of the spring broods. Russian-thistle, mustards, and filaree are the most important weed hosts in Utah and Idaho. They serve not only as hosts for the leafhopper but also may be source plants from which the insects obtain the curly top virus.

Investigations by the Division of Sugar Plant Investigations, conducted in cooperation with the Bureau of Entomology and Plant Quarantine, have shown that overgrazing is the most important factor causing an increase in undesirable weed hosts in the range lands, which are breeding grounds of the beet leafhopper. Properly controlled grazing allows the reestablishment of native range grasses that are not host plants for the leafhopper. It has been demonstrated that controlled grazing for even 3 or 4 years accomplishes a great deal in reducing leafhopper breeding areas, and, consequently, reduces the hazard of heavy migrations of leafhoppers into the beet fields when the beets are small.

With the resistant varieties now available, it is possible, by following good cultural practices and by coordinated efforts, to reduce leafhopper populations by control of the natural breeding areas, to produce good crops of sugar beets consistently in spite of curly top.

## OTHER DISEASES

In Utah, Idaho, Oregon, and Washington, other diseases of sugar beets are of minor importance as compared with curly top.

Damping-off, or "black root," is sometimes a cause of poor stands, especially in years when conditions favor the development of the fungi. The trouble is most prevalent when the spring is late and wet. In some areas where damping-off of seedling beets is serious, improved stands have been obtained by seed treatments. However, in this area the principal control measures consist of early cultivation and crop rotation.

Each year some damage results in fields from root rots, and in a few cases the losses are severe. The rots for the most part are attrib-

utable to *Rhizoctonia* spp. (*Corticum vagum* B. and C. var. *solani* Burt. and its allies). Many physiological races, which vary in their virulence to sugar beets and to other plants, have been shown to exist within this fungus group. There is experimental evidence that the *Rhizoctonia* spp. isolated from potato plants affected with black scurf do not cause rotting of sugar-beet roots that have attained fair size, hence sugar beets may safely follow potatoes in the rotation. Rotting of roots in the field and in the storage pile has been shown to be greatly reduced if conditions for growth are kept optimum by proper watering and high fertility, especially by the use of phosphate fertilizers. Crop rotation as a means of soil sanitation and improved cultural practices are the only promising remedial measures.

## NEMATODES [1]

Large areas of land, normally planted to sugar beets in Utah and Idaho, are already infested with the sugar-beet nematode. The pest

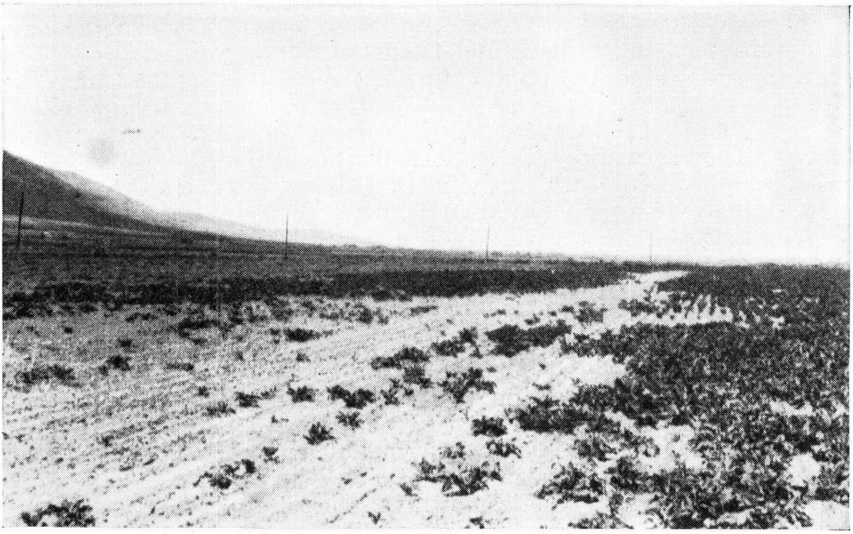

FIGURE 28.—Injury from severe nematode infestation. This field illustrates how nematode infestation is spread in the direction of irrigation and cultivation. (Photograph by Gerald Thorne.)

continues to be introduced further into fields largely through the spreading of "dump dirt" from beet deliveries and the transfer of dirt from one field to another by contract haulers. After establishment in the field, irrigation and cultivation tend to move the nematodes so that larger and larger areas are occupied. Most of the infested areas are now being controlled by crop rotation. This practice reduces the nematode infestation to the point where there are few crop failures, but occasionally fields are planted without proper rotation, with resultant serious injury to the crop (fig. 28).

There are four stages in the life history of the sugar-beet nematode: The egg, the larva, the adult, and the dark-colored cyst, or resting

[1] This section has been reviewed by the Division of Nematology, Bureau of Plant Industry. For more detailed information see Farmers' Bulletin 1514, Control of Sugar-Beet Nematode by Crop Rotation.

stage. Under favorable conditions of moisture, temperature, and suitable host plants nematode populations will increase rapidly, and this fact must be kept in mind when considering nematode control.

Nematodes attack the roots of sugar beets and, in severely infested fields, either kill them or cause them to become stunted and covered with short, hairy rootlets somewhat resembling those caused by curly top. Generally the injury is first noted immediately after thinning, when areas appear in which the young beets die or fail to make normal growth. As the season advances, the infested plants are detected by their less thrifty appearance and also by the fact that they wilt much more readily. Inspection by carefully digging the plants will usually reveal the small, whitish, lemon-shaped females clinging to the roots. These females are large enough to be seen with the unaided eye.

## CONTROL OF NEMATODES

If a field is found to be infested with nematodes, measures must be taken to combat the pest, as the situation will become so serious that

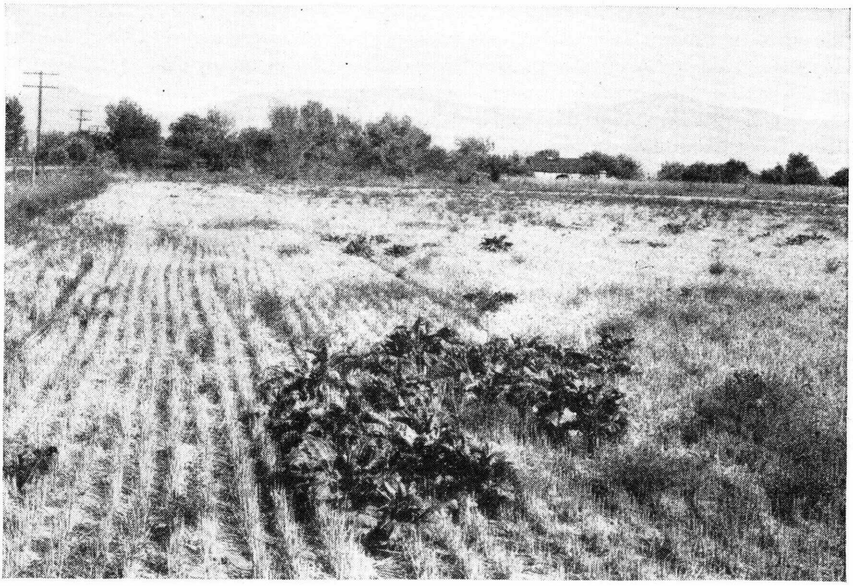

FIGURE 29.—Volunteer beets that grew in the grain crop following beets. These volunteers came from bolters that were allowed to mature seed in the commercial beet crop.

profitable yields of beets cannot be obtained. The only known practical method of reducing nematode infestation is to have nonhost plants in the rotation. A large number of crops can be used, such as legume forage crops, beans, peas, potatoes, small grains, corn, tomatoes, and celery. In a long rotation alfalfa plays a major role. For a rotation to be effective in reducing nematode populations it is absolutely necessary that no host plants be allowed to grow for a period of 3 to 4 years or the entire purpose of the rotation is defeated (fig. 29). This means that in addition to not growing sugar beets the land must be kept free from such common weeds as mustard, lambs-

quarters, knotweed, ladysthumb, purslane, curly dock, black nightshade; and from such crop plants as garden and stock beets, cabbage, cauliflower, and turnips. It should be pointed out that a profitable crop of sugar beets having been produced in a suitable nonhost rotation, the rotation should not be disrupted by trying to produce two successive crops of beets after a rotation on nematode-infested land, because the second-year beet crop will be severely injured by the nematodes that have developed from the few that always manage to survive during a rotation.

As previously stated (p. 44), the nematode generally enters noninfested fields by "dump dirt," which is the soil and trash screened from beets delivered at the receiving stations, and for this reason the practice of spreading such screenings in sugar-beet fields should be discontinued, and contract hauling should be controlled as carefully as is feasible.

## HAIL DAMAGE

Severe localized hailstorms frequently occur in the intermountain area. The time of the season that a hailstorm occurs determines the amount of damage done. Storms occurring when the beets are small or shortly after thinning do the most damage, as frequently the plants are killed. Hail later in the season only destroys the leaves, and root growth is checked during the interval that new foliage is being produced. The sugar beet has remarkable ability to recover from hail injury, and no cash crop available for culture in this region can compare with the sugar beet in this respect. The recovery from hail injury has been shown experimentally to be more rapid with beets fertilized with superphosphate than where the beets were not fertilized.

## INSECTS[2]

The common insect pests of sugar beets in the intermountain area of Utah, Idaho, Oregon, and Washington are the beet leafhopper, the beet webworm, the beet armyworm, flea beetles, blister beetles, the beet leaf beetle, grasshoppers, leaf miners, wireworms, white grubs, the sugar-beet root aphid, and the sugar-beet root maggot. The outstanding pest of this group is the beet leafhopper, although the other insect pests mentioned are of local importance periodically.

**Many of the compounds used in the control measures outlined in the following paragraphs are injurious to human beings and animals. Therefore, care should be taken in handling any of them. If they are used in dust form, care should be taken not to inhale them; if they are used in liquid form, care should be taken in pouring out the used solution to see that it does not stand in puddles but soaks into the ground. Powders and tablets of any of these compounds should be kept in a safe place out of reach of children.**

### BEET LEAFHOPPER

The beet leafhopper (*Eutettix tenellus* (Bak.)), sometimes known as the "white fly," is considered the most important insect enemy of sugar beets in the intermountain area. Although this insect rarely

[2] Prepared in the Division of Truck Crop and Garden Insect Investigations, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

becomes sufficiently numerous to cause any great damage by its feeding activities, some of these leafhoppers carry and transmit the virus of the curly top disease. With their sucking mouth parts these leafhoppers pierce and remove sap from diseased plants and in like manner transmit the curly top disease to the healthy plants on which they feed. The appearance of plants affected by the curly top disease and the effect of the disease on infected plants have been described on pages 42 and 43.

Because the beet leafhopper is migratory in its habits and also because the damage is caused by the virus of the curly top disease that it carries and not by the feeding of the insect alone, the control of the beet leafhopper is a difficult problem. Recent experiments with insecticides have given encouraging indications that some measure of control of the beet leafhopper on sugar beets can be obtained by direct methods, but these experiments have not yet reached a stage where specific recommendations for the application of insecticides can be made. Prevention of serious damage by the beet leafhopper by certain approved cultural methods and by controlling its weed host plants, as well as by the use of varieties of sugar beets that are resistant to the curly top disease, has been discussed on pages 42 and 43.

## BEET WEBWORM

The small caterpillars of the beet webworm (*Loxostege sticticalis* (L.)) first devour small patches on the under side of the leaves of sugar beets, but as they grow older and larger they eat practically all the foliage of infested plants and sometimes feed on the petioles and on the crowns of the beet roots. These caterpillars develop so fast and eat so much of the foliage within a short time that severe injury is often caused to the crop before the growers become aware of the danger.

This pest is most easily controlled by spraying infested fields, or parts thereof, as soon as the newly hatched caterpillars are observed, with a spray containing 8 pounds of paris green per 100 gallons of water.

## BEET ARMYWORM

The beet armyworm (*Laphygma exigua* (Hbn.)) causes practically the same type of injury that has been described for the beet webworm except that the feeding of the small beet armyworms results in a lace-like appearance of infested sugar-beet leaves. The larger armyworm caterpillars eat out large parts of the leaves and also feed on the crowns of the beet roots. In instances where these caterpillars are exceedingly numerous they sometimes feed on the underground part of the beet roots.

The principal control measure for the beet armyworm is the same as that mentioned for the beet webworm.

## FLEA BEETLES

Several species of flea beetles often damage sugar beets in the intermountain area. The principal species ordinarily responsible for such damage are the banded flea beetle (*Systena taeniata* (Say)), the potato flea beetle (*Epitrix cucumeris* (Harr.)), and the hop flea beetle (*Psylliodes punctulata* Melsh.). These flea beetles feed on the leaves of sugar-beet plants, gnawing small holes through the leaves, which

often appear as though fine shot had been fired through them. The beetles usually feed from the under side of the leaf. In some cases the substance of the leaf is eaten through only to the upper epidermis. When the flea beetles are numerous on small sugar-beet plants their extensive feeding activities often cause the death of severely injured plants and in extreme cases necessitate the replanting of fields or parts of fields.

It is difficult to provide complete protection for sugar-beet plants against injury from flea beetle attack, but good results in preventing severe injury by these pests have been obtained with several insecticides, including (1) a combination spray composed of 4 pounds of calcium arsenate in 50 gallons of bordeaux mixture (4–4–50) applied at the rate of 75 gallons per acre; (2) a dust mixture composed of 92½ percent of dusting sulfur and 7½ percent of paris green, by weight; (3) a dust mixture containing 1 percent of rotenone; and (4) a spray made of 1 pound of derris or cube root powder (containing 2 percent of rotenone) in 50 gallons of water.

## BLISTER BEETLES

Blister beetles are common pests in sugar-beet fields and are often very destructive. The principal species found attacking sugar beets in the intermountain area are the black blister beetle (*Epicauta pennsylvanica* (Deg.)), the spotted blister beetle (*Epicauta maculata* (Say)), and the ash-gray blister beetle (*Macrobasis unicolor* (Kby.)). Blister beetles travel like armyworms, and for this reason they are sometimes called army beetles. They are greedy feeders and often travel in lines, eating everything in their path. In sugar-beet fields the blister beetles sometimes assemble in large numbers in a certain part of the field, and, after devouring all the leaves on the plants in a comparatively small area, they may fly to another part of the same field or to an adjacent or nearby field and repeat the performance.

No entirely satisfactory methods have been developed for the control of blister beetles. The paris green spray mentioned on page 49 as a control for the beet webworm and beet armyworm will repel the beetles, although it will not kill them. A dust mixture composed of 1 pound of paris green to 5 pounds of hydrated lime is also useful for this purpose. Spraying or dusting with a strong dose of pyrethrum is effective if the beetles are concentrated in small areas. Under some circumstances, when very small parts of sugar-beet fields are infested, hand-picking of the beetles is practical, but gloves should be worn while handling the beetles because they may blister a tender skin. Also it is often feasible to knock the beetles into pails or pans containing a small quantity of water upon which a little kerosene has been poured.

## BEET LEAF BEETLE

In the intermountain area sugar beets are subject to attack by the beet leaf beetle (*Monoxia puncticollis* (Say)), known in some localities as the "alkali bug" or "French bug." The principal injury caused by the pest is due to the feeding of the larvae on the sugar-beet leaves, although the adults also inflict considerable damage. Both the larvae and adults eat holes similar to those caused by flea beetles, although larger. When numerous, these insects entirely consume the foliage

on infested plants or injure such plants so severely that they die. Ordinarily the injury by this insect is most pronounced on the borders of fields next to wasteland that is damp and contains excessive percentages of alkali.

Although the application of insecticides has not been entirely effective in controlling the beet leaf beetle, fairly good results can be obtained by applying to infested parts of sugar-beet fields a spray consisting of 4 pounds of paris green in 100 gallons of water. A dust mixture consisting of 1 pound of paris green to 10 pounds of flour or of hydrated lime is also useful for this purpose. As the beetles usually congregate during the fall under tufts of grass, heaps of weeds, or similar shelter in low damp spots along field borders or nearby, the burning of these overwintering shelters during the late fall, winter, or early spring will often reduce the numbers of these insects to such an extent as to prevent a severe infestation during the following crop season.

## GRASSHOPPERS

Grasshoppers are considered important pests of sugar beets. They cause great damage to this crop periodically by devouring the leaves and by feeding on the crowns to such an extent as to prevent the growth of new leaves, thus killing the affected plants. Several species of grasshoppers are responsible for such damage, the more common ones being the two-striped grasshopper (*Melanoplus bivittatus* (Say)), the differential grasshopper (*Melanoplus differentialis* (Thos.)), the lesser migratory grasshopper (*Melanoplus mexicanus* (Sauss.)), and the clear-winged grasshopper (*Camnula pellucida* (Scudd.)).

The most widely used and practical control measure against grasshoppers is poisoned bait. Although several formulas are commonly used in preparing poisoned baits, the following formula has been found to be very effective:

| | |
|---|---|
| Mill-run bran, mixed feed, or shorts | 25 pounds. |
| Sawdust (three times the bulk of mill-run bran) | 3½ bushels. |
| Liquid sodium arsenite | ½ gallon. |
| Water | 10–12 gallons. |

Finely divided crude arsenic, obtained from copper smelters, or paris green can be substituted for the liquid sodium arsenite at the rate of 5 pounds for each 100 pounds of bran or equal bulk of sawdust. Sodium fluosilicate, at the rate of 4 pounds to 100 pounds of bran or equal bulk of sawdust, may also be substituted for the other poisons mentioned. This bait can be mixed by hand on a tight floor or in a wagon box or similar container when small quantities of bait are required, or by a power mixer when large quantities are needed. For detailed information on the methods of mixing and applying these baits and the precautions that should be observed to prevent injury to operators, livestock, or poultry, obtain a copy of Farmers' Bulletin 1828, Grasshoppers and Their Control, issued by the United States Department of Agriculture, or write to your county agricultural agent, State agricultural experiment station, State agricultural college, or State department of agriculture.

## LEAF MINERS

Two species of leaf miners, known as the beet leaf miner (*Pegomyia vicina* Lintner) and the spinach leaf miner (*Pegomyia hyoscyami*

(Panz.)), are often found infesting the leaves of sugar beets. These leaf miners feed between the upper and lower surfaces of the leaves and form a large, irregular-shaped mine or blotch. The infested leaves usually turn brown and die prematurely. In instances where a large percentage of the leaves are infested with leaf miners the resulting loss of foliage may affect seriously the growth of the plant and the yield of beet roots, but ordinarily these insects, although they cause easily noticeable damage, do not cause appreciable losses to the sugar-beet crop.

No effective means of insecticidal control has been developed for leaf miners in sugar-beet plants. As these insects breed commonly in lambsquarters, the destruction of this weed in any given locality will aid in keeping the numbers of leaf miners at a low level.

## WIREWORMS

Wireworms of several species are one of the limiting factors in the growing of sugar beets in the intermountain area. The more common species of wireworms found in sugar-beet fields of this area are the sugar-beet wireworm (*Limonius californicus* (Mann.)) and the Pacific coast wireworm (*Limonius canus* Lec.). Wireworms are especially injurious to the small beet plants, although they also feed on the seed in the soil. The wireworms feed on and often sever the small taproot just below the soil surface. Such injury results in a noticeable wilting of the beet leaves, and in cases of severe injury it causes the stunting or death of infested plants.

The control of wireworms in fields of sugar beets by the use of chemicals has proved to be a difficult problem, and at present no specific recommendations are available for the use of such materials in combating these pests. Some degree of control can be obtained, however, by adopting the following cultural practices:

(1) Careful planning to avoid the planting of sugar-beet seed late in April or early in May, at which time the majority of the wireworms are near the soil surface, will tend to minimize the damage to the seed and young plants from wireworm feeding. If, despite these precautions, any large number of young plants are being killed by wireworms at the time of normal thinning operations, the thinning of the plants should be delayed for a week or 10 days, which will give a better chance to thin properly the surviving plants. (2) As alfalfa creates relatively unfavorable conditions for the development of wireworms, it is advisable to follow this crop with sugar beets, whenever agronomic conditions will permit, in soils where damage by wireworms may be expected. (3) Wireworms have a tendency to increase rapidly in numbers when red clover or sweetclover is grown more than one season on infested land. In districts where wireworms are known to be present, therefore, these crops should not be grown in rotation with sugar beets. (4) Drying out the soil by withholding irrigation water is an effective method of killing wireworms. This method may be followed to advantage in fields of such deep-rooted crops as alfalfa or fall grain which the grower plans to use for sugar beets the following year, although the soil drying involves some reduction in the yield of the affected crop. If soil drying can be fitted into the rotation so that any field that shows heavy damage from wireworms can be dried out every fifth or sixth year, the wireworm population can be kept at

such a low level that but little damage will occur when sugar beets are planted in the field.

## WHITE GRUBS

In certain areas and during some seasons sugar beets are damaged by various species of white grubs (*Phyllophaga* spp.), which are the larvae of May beetles, or June bugs. A full-grown white grub is dirty white in appearance, has a brown or black head, and is 2 inches or more in length when extended. These grubs never appear above ground but feed on the taproot and fibrous roots of small sugar beets and also eat large holes in the sides of sugar-beet roots. If the injury is severe, particularly to small sugar-beet plants, the leaves of affected plants wither prematurely and then die.

Although there are no satisfactory means of destroying white grubs in large fields of sugar beets, certain cultural and other practices will reduce the damage greatly. These practices are as follows: (1) As the beetles which lay eggs that develop into white grubs usually deposit these eggs in fields of grass or small grain, the planting of sugar beets should not follow these crops unless it is known that the soil is free of these pests. (2) Hogs are very fond of white grubs and under some conditions may be used to advantage to rid infested fields of these grubs. Such fields should not be pastured with hogs oftener than once in 3 years, however, because the hogs might become infested with the giant thorn-headed worm as the white grubs serve as the intermediate host of this parasite of swine. (3) Poultry aid in the control of white grubs if allowed the run of infested fields during plowing or cultivation. (4) Late-summer or early-fall plowing of infested fields intended for sugar-beet planting aids to some extent in reducing damage by white grubs, as this operation kills many of the grubs.

## SUGAR-BEET ROOT APHID

The sugar-beet root aphid (*Pemphigus betae* Doane) is a widely distributed pest of sugar beets and sometimes causes important losses. When plants are severely infested by this aphid the color of the leaves changes from the normal dark green to a light yellow green, and the leaves wilt as if the plants needed irrigation. In advanced stages of infestation the beet roots become shrunken and loose in the ground. Upon examination they will be found to be infested by the root aphids and very much wrinkled in appearance.

No direct methods of controlling the sugar-beet root aphid have been developed, but some measure of relief can be obtained by the following indirect methods of control: (1) Because the root aphid does not multiply as rapidly in moist soil as in dry, early and frequent irrigations of infested fields, usually during June and July, are effective in greatly reducing the numbers of these pests. (2) As the narrowleaved cottonwood and the cottonwood known locally as balm-of-gilead serve as breeding grounds for this root aphid, the destruction of these trees growing near sugar-beet fields, when feasible, aids in reducing the number of the aphids, although in some cases the winged form of the insect will fly some distance from cottonwood trees to beet fields.

## SUGAR-BEET ROOT MAGGOT

The sugar-beet root maggot (*Eurycephalomyia myopaeformis* (Roeder)) is not widely distributed in the sugar-beet-growing districts

of the intermountain area, but occasionally causes severe injury in some parts of individual fields, particularly in relatively dry, sandy soil. These maggots feed on the taproots and fibrous roots of sugar beets, sometimes cutting off the taproot and causing the death of affected plants. This latter type of injury is most likely to occur when the soil in sugar-beet fields becomes so dry that the maggots are forced to burrow deeply to find suitable moisture conditions.

Although no direct method of controlling the sugar-beet root maggot is known, it is believed that irrigation practices that keep a proper moisture content in infested sugar-beet fields late in the spring and early in the summer keep the maggots feeding so high on the roots as to prevent serious damage to the crop.

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